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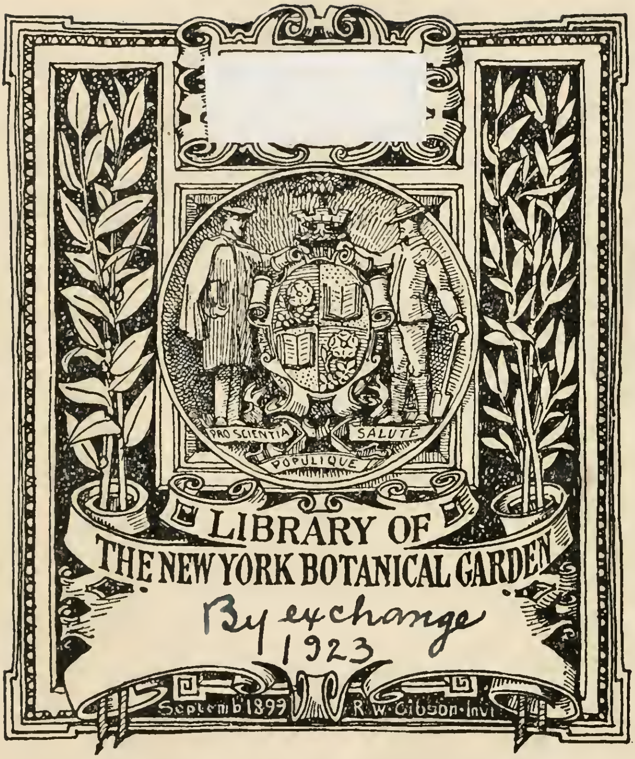
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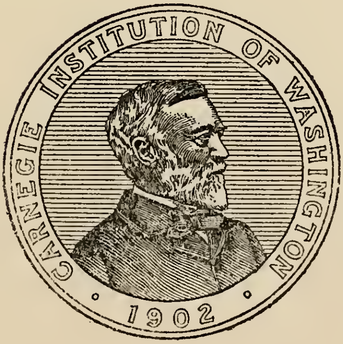
1922



Published by the Carnegie Institution of Washington
Washington, January, 1923

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President of the Institution.
John C. Merriam.

Trustees.
Elihu Root, *Chairman.*
Charles D. Walcott, *Vice-Chairman.*
W. Cameron Forbes, *Secretary.*

bert S. Brookings.
hn J. Carty.
eveland H. Dodge.
arles P. Fenner.
Cameron Forbes.
yron T. Herrick.
erbert Hoover.
arles L. Hutchinson.
Henry Cabot Lodge.
Andrew J. Montague.
William W. Morrow.
James Parmelee.
Wm. Barclay Parsons.
Stewart Paton.
Henry S. Pritchett.
Elihu Root.
Martin A. Ryerson.
Theobald Smith.
Charles D. Walcott.
Henry P. Walcott.
William H. Welch.
Henry White.
George W. Wickersham.
Robert S. Woodward.

Executive Committee.
Elihu Root, *Chairman.*
ohn J. Carty.
. Cameron Forbes.
ohn C. Merriam.
Wm. Barclay Parsons.
Stewart Paton.
Henry S. Pritchett.
Henry White.

Finance Committee.
Henry S. Pritchett, *Chairman.*
Wm. Barclay Parsons.
George W. Wickersham.

Auditing Committee.
R. S. Brookings, *Chairman.*
Charles L. Hutchinson.
George W. Wickersham.

*Ex-officio member.

LIST OF PRESENT AND FORMER TRUSTEES.

*Alexander Agassiz,	1904–05
*John S. Billings,	1902–13
Robert S. Brookings,	1910–
*John L. Cadwalader,	1903–14
John J. Carty,	1916–
Cleveland H. Dodge,	1903–
*William E. Dodge,	1902–03
Charles P. Fenner,	1914–
Simon Flexner,	1910–14
W. Cameron Forbes,	1920–
*William N. Frew,	1902–15
Lyman J. Gage,	1902–12
*Daniel C. Gilman,	1902–08
*John Hay,	1902–05
Myron T. Herrick,	1915–
*Abram S. Hewitt,	1902–03
*Henry L. Higginson,	1902–19
*Ethan A. Hitchcock,	1902–09
*Henry Hitchcock,	1902–02
Herbert Hoover,	1920–
*William Wirt Howe,	1903–09
Charles L. Hutchinson,	1902–
*Samuel P. Langley,	1904–06
*William Lindsay,	1902–09
Henry Cabot Lodge,	1914–
*Seth Low,	1902–16
*Wayne MacVeagh,	1902–07
*D. O. Mills,	1902–09
*S. Weir Mitchell,	1902–14
Andrew J. Montague,	1907–
William W. Morrow,	1902–
James Parmelee,	1917–
Wm. Barclay Parsons,	1907–
Stewart Paton,	1915–
George W. Pepper,	1914–20
Henry S. Pritchett,	1906–
Elihu Root,	1902–
Martin A. Ryerson,	1908–
Theobald Smith,	1914–
*John C. Spooner,	1902–07
William H. Taft,	1906–15
Charles D. Walcott,	1902–
Henry P. Walcott,	1910–
William H. Welch,	1906–
*Andrew D. White,	1902–16
*Edward D. White,	1902–03
Henry White,	1913–
George W. Wickersham,	1909–
Robert S. Woodward,	1905–
*Carroll D. Wright,	1902–08

*Deceased.

Besides the names enumerated above, the following were ex-officio members of the Board of Trustees under the original charter, from the date of organization until April 28, 1904:

The President of the United States.
The President of the Senate.
The Speaker of the House of Representatives.
The Secretary of the Smithsonian Institution.
The President of the National Academy of Sciences.

STAFF OF INVESTIGATORS FOR YEAR 1922.

epartment of Botanical Research:

Daniel T. MacDougal, Director.
William A. Cannon.
J. M. McGee.
Forrest Shreve.
H. A. Spoehr.
Godfrey Sykes.

epartment of Embryology:

George L. Streeter, Director.
Chester H. Heuser.
Margaret R. Lewis.
W. H. Lewis.
A. H. Schultz.

epartment of Genetics:

Charles B. Davenport, Director.
H. H. Laughlin, Assistant Director.
*C. C. Little, Assistant Director.
*E. G. Anderson.
H. J. Banker.
A. M. Banta.
John Belling.
A. F. Blakeslee.
A. H. Estabrook.
M. E. Farnham.
W. S. Fisher (temporary).
J. A. Harris.
E. C. MacDowell.
C. W. Metz.
Elizabeth B. Muncey.
Louise A. Nelson.
Oscar Riddle.
*J. R. Spannuth (temporary).

eophysical Laboratory:

Arthur L. Day, Director.
L. H. Adams.
Eugene T. Allen.
M. Aurousseau.
N. L. Bowen.
Pentti Eskola.
C. N. Fenner.
J. W. Greig.
R. H. Lombard.
H. E. Merwin.
G. W. Morey.
Eugen Posnjak.
H. S. Roberts.
E. S. Shepherd.
F. Hastings Smyth.
Robert B. Sosman.
H. S. Washington.
Walter P. White.
E. D. Williamson.
Fred. E. Wright.
R. W. G. Wyckoff.
E. G. Zies.

epartment of Historical Research:

J. Franklin Jameson, Director.
Edmund C. Burnett.
Frances G. Davenport.
Mary F. Griffin.
Waldo G. Leland.
Charles D. Paullin.
Leo F. Stock.

epartment of Marine Biology:

†Alfred G. Mayor, Director.

Investigators connected with this Department during the year.

aul Bartsch (U. S. National Museum).
lric Dahlgren (Princeton University).
ohn H. Gerould (Dartmouth College).
. N. Harvey (Princeton University).
. B. Lipman (University of California).
Villiam H. Longley (Goucher College).
ergius Morgulis (Creighton University)
Frank A. Potts (University of Cambridge, England).
Asa A. Schaeffer (University of Tennessee).
William A. Setchell (University of California).
T. Wayland Vaughan (U. S. Geological Survey).

epartment of Meridian Astrometry:

Benjamin Boss, Director.
Sebastian Albrecht.
Sherwood B. Grant.
Heroy Jenkins.
Harry Raymond.
Arthur J. Roy.
W. B. Varnum.
Ralph E. Wilson.

*Resigned. †Deceased.

Staff of Investigators for Year 1922—*Continued.*

Mount Wilson Observatory:

George E. Hale, Director.
Walter S. Adams, Assistant Director.
Alfred H. Joy, Secretary.
F. H. Seares, Supt. Computing Division.
A. S. King, Supt. Physical Laboratory.
J. A. Anderson.
Harold D. Babcock.
Ferdinand Ellerman.
Edwin P. Hubble.
Milton L. Humason.
Paul W. Merrill.
Seth B. Nicholson.
Francis G. Pease.
Edison Pettit.
R. F. Sanford.
Gustaf Strömberg.
Charles E. St. John.
A. van Maanen.

Nutrition Laboratory:

Francis G. Benedict, Director.
*Marion L. Baker.
T. M. Carpenter.
E. L. Fox.
*Mary F. Hendry.
*W. R. Miles.
E. S. Mills.

Department of Terrestrial Magnetism:

Louis A. Bauer, Director.
J. A. Fleming, Assistant Director.
J. P. Ault.
S. J. Barnett.
D. G. Coleman.
C. R. Duvall.
H. M. W. Edmonds.
C. C. Ennis.
H. W. Fisk.
O. H. Gish.
R. H. Goddard.
John W. Green.
J. T. Howard.
H. F. Johnston.
W. A. Love.
S. J. Mauchly.
W. C. Parkinson.
W. J. Peters.
J. Shearer.
A. Thomson.
G. R. Wait.
W. F. Wallis.

Ecological Research:

Frederic E. Clements, Associate.
G. W. Goldsmith.
H. M. Hall.
Frances L. Long.
J. V. G. Loftfield.

Middle American Archœology:

Sylvanus G. Morley, Associate.
*Carl E. Guthe, Research Associate.

Physiological Chemistry:

T. B. Osborne, Research Associate (Connecticut Agric. Exper. Station).
L. B. Mendel, Research Associate (Yale University).
A. J. Wakeman.
C. S. Leavenworth.
Helen Cannon.
H. B. Vickery.

Biology:

T. H. Morgan, Research Associate (Columbia University).
C. B. Bridges.
A. H. Sturtevant.

Other Investigators Primarily Connected with Institution:

Henry Bergen, Research Associate in Early English Literature.
Ralph W. Chaney, Research Associate in Palæobotany.
Oliver P. Hay, Associate in Palæontology.
Elias A. Lowe, Associate in Palæography.
Albert Mann, Research Associate in Biology.
George Sarton, Associate in the History of Science.
Esther B. Van Deman, Associate in Roman Archæology.
George R. Wieland, Associate in Palæontology.
Harry O. Wood, Research Associate in Seismology.

*Resigned.

Additional Research Associates Connected with other Institutions:

Ernst Antevs (Sweden), Geology.
Carl Barus (Brown University), Physics.
V. Bjerknes (University of Bergen, Norway), Meteorology.
E. C. Case (University of Michigan), Palæontology.
W. E. Castle (Harvard University), Biology.
T. C. Chamberlin (University of Chicago), Geology.
H. D. Fish (University of Pittsburgh), Zoology.
John F. Hayford (Northwestern University), Physics.
Ellsworth Huntington (Yale University), Geology.
*J. C. Kapteyn (University of Groningen), Astronomy.
C. A. Kofoid (University of California), Zoology.
B. E. Livingston (Johns Hopkins University), Botany.
H. A. Lorentz (Leiden), Physics.
A. A. Michelson (University of Chicago), Astronomy.
R. A. Millikan (California Institute of Technology), Physics.
Frank Morley (Johns Hopkins University), Mathematics.
F. R. Moulton (University of Chicago), Mathematical Physics.
E. L. Nichols (Cornell University), Physics.
A. A. Noyes (California Institute of Technology), Chemistry.
W. J. V. Osterhout (Harvard University), Botany.
T. W. Richards (Harvard University), Chemistry.
J. N. Rose (U. S. National Museum), Botany.
Henry N. Russell (Princeton University), Astronomy.
H. C. Sherman (Columbia University), Chemistry.
Edgar F. Smith (University of Pennsylvania), Chemistry.
John S. P. Tatlock (Leland Stanford Junior University), Literature.
Lewis H. Weed (Johns Hopkins University), Anatomy.

*Deceased.

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ORGANIZATION, PLAN AND SCOPE.

The Carnegie Institution of Washington was founded by Mr. Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him January 19, 1911; so that the present endowment of the Institution has a par value of twenty-two million dollars. The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution*, articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of *The Carnegie Institution of Washington*. (See existing Articles of Incorporation on the following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the Trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President of the Institution as chief executive officer.

The Articles of Incorporation of the Institution declare in general "that the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind." Three principal agencies to forward these objects have been developed. The first of these involves the establishment of departments of research within the Institution itself, to attack larger problems requiring the collaboration of several investigators, special equipment, and continuous effort. The second provides means whereby individuals may undertake and carry to completion investigations not less important but requiring less collaboration and less special equipment. The third agency, namely, a division devoted to editing and to printing books, aims to provide adequate publication of the results of research coming from the first two agencies and to a limited extent also for worthy works not likely to be published under other auspices.

FEB 13 1923

ARTICLES OF INCORPORATION.

Public No. 260.—An Act To incorporate the Carnegie Institution of Washington.

Be in enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the persons following, being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

Sec. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

Sec. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D.

Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinabove referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corporation hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia, January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

Sec. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

Sec. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

Sec. 9. That this Act shall take effect immediately.

Approved, April 28, 1904.

BY-LAWS OF THE INSTITUTION.

Adopted December 13, 1904. Amended December 13, 1910, and December 13, 1912.

Article I.

THE TRUSTEES.

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members The Trustees shall hold office continuously and not for a stated term.

2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.

3. No Trustee shall receive any compensation for his services as such.

4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

Article II.

MEETINGS.

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year.

2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.

3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

Article III.

OFFICERS OF THE BOARD.

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.

2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties. He shall execute all deeds, contracts or other instruments on behalf of the corporation, when duly authorized.

Article IV.

EXECUTIVE ADMINISTRATION.

The President.

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall affix the seal of the corporation whenever authorized to do so by the Board of Trustees or by the Executive Committee or by the Finance Committee. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

Article V.

COMMITTEES.

1. There shall be the following standing Committees, viz., an Executive Committee, a Finance Committee, and an Auditing Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of expenditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

ARTICLE VI.

FINANCIAL ADMINISTRATION.

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

ARTICLE VII.

AMENDMENT OF BY-LAWS.

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

MINUTES

OF THE

TWENTY-THIRD MEETING OF THE BOARD OF TRUSTEES

ABSTRACT OF MINUTES OF THE TWENTY-THIRD MEETING OF BOARD OF TRUSTEES.

The meeting was held in Washington in the Board Room of the Administration Building, on Friday, December 15, 1922, and was called to order at 10 a. m. by the Chairman, Mr. Root.

Upon roll-call the following Trustees responded: Robert S. Brookings, John J. Carty, W. Cameron Forbes, Charles L. Hutchinson, Henry Cabot Lodge, Andrew J. Montague, James Parmelee, Wm. Barclay Parsons, Stewart Paton, Henry S. Pritchett, Elihu Root, Martin A. Ryerson, Charles D. Walcott, William H. Welch, Henry White, George W. Wickersham. The President of the Institution, John C. Merriam, was also present.

The minutes of the twenty-second meeting were approved as printed and submitted to the members of the Board.

Reports of the President, the Executive Committee, the Auditor, the Finance Committee, the Auditing Committee, and of Directors of Departments, Associates, and Research Associates of the Institution were presented and considered.

The following appropriations for the year 1923 were authorized:

Insurance Fund	$9,500
Pension Fund	40,000
Administration	63,500
Publication (including Division of Publications)	92,500
Departments and Divisions of Research	927,662
Associates of Institution	18,600
Minor Grants	150,385
Index Medicus	17,500
General Contingent Fund	45,000
Total	$1,364,647

The Board expressed by resolution its appreciation of the cooperation of the Carnegie Corporation of New York in appropriating funds on condition that they be expended by the Institution for a study of the origin and effects of the recent earthquake in Chile.

The resignations of Mr. Cleveland H. Dodge as Secretary of the Board and as a member of the Executive Committee and of the

Finance Committee, and of Dr. Charles D. Walcott as a member of the Executive Committee were accepted with regret.

Mr. W. Cameron Forbes was elected Secretary of the Board, thus becoming an ex-officio member of the Executive Committee, and Mr. John J. Carty was elected a member of the Executive Committee for the unexpired term of Dr. Walcott ending in 1923. Mr. Wm. Barclay Parsons was also elected a member of the Finance Committee for the unexpired term of Mr. Dodge, ending in 1924.

The meeting adjourned at twelve o'clock.

REPORT OF THE PRESIDENT

OF THE

CARNEGIE INSTITUTION OF WASHINGTON

FOR THE YEAR ENDING OCTOBER 31, 1922

REPORT OF THE PRESIDENT
OF THE
CARNEGIE INSTITUTION OF WASHINGTON.

In conformity with Article IV, section 2, of the By-Laws of the Carnegie Institution of Washington, the President has the honor to submit the following report on the work of the Institution for the fiscal year ending October 31, 1922, along with suggestions concerning certain of our general problems and provisional recommendation of appropriations for the ensuing year.

In entering upon the third decade of the Institution's activities, it has seemed desirable to take stock of our assets and to review our aims.

Present Problems.

With continued high cost of everything involved in research, we find that for 1923 our funds immediately available for investigations will be measurably smaller, while the needs for study have increased beyond the number for which provision has been made in budgets of recent years. It is a credit to our staff that in the process of solving many difficult problems unanswered questions grow more numerous with the progress of investigation, and that the opportunities for accomplishment in constructive work continue to increase. It is natural and commendable that our researchers desire to see all new questions answered, but it is a part of our problem to discover how far effectiveness in expenditure of energy and funds makes it desirable that we select from available opportunities those which most clearly represent the duties of this Institution.

On the purely material side we have completed an inventory of all equipment possessed by the Institution. We carry our own insurance and it is desirable at this time of changing costs to test the effectiveness of the system in operation.

Immeasurably more important than the material inventory has been the attempt to review our research accomplishments of the past twenty years and to see them in the light of the present status of knowledge and the responsibilities of research in the future. As our work is of a type dealing at the same time with the rapidly changing outside margin of knowledge and with the modifications in organization which these changes make necessary we must expect wide variability in operation if the Institution serves its purpose.

It does not seem advisable in this report to attempt an outline of all past work in our many departments. There does seem to be appropriateness in consideration of the position of the Institution as a whole with reference to other kinds of agencies with which we cooperate in the effort to make knowledge advance at a rate sufficient to keep pace with human needs.

The fact that the Carnegie Institution of Washington is devoted to fundamental investigations is sometimes understood to mean that its problems are therefore identical with those of other investigating organizations. Although this is true in the generic sense, each of the several types of research activities in this country has its peculiar problem. The kinds of work overlap, but each body has an individuality and should have a special function making possible a special contribution. It is this differentiation in purpose that, with full cooperation, makes possible the greatest advances in knowledge.

While it is the part of scientific efficiency to encourage concentration of certain research institutions upon particular questions, it is improbable that we shall ever make the assumption that any one of these has exclusive rights to any special subject. However this type of differentiation may shape itself, it will always be desirable to have among the various research bodies a general difference in attitude toward problems. It is in this aspect of definition or function that we can see most clearly how the Carnegie Institution is to meet its peculiar obligations without destructive competition and without hindrance to other work.

In universities the indispensable element of research must always have such free range as will make it possible for the instructor to keep a vivid interest in the constructive use of knowledge and thus be able to develop this attitude in his students. But universities deal by definition with the whole breadth of knowledge and must work continuously in all the major groups of subjects. It is therefore inevitable that under normal conditions research support in these institutions will be rather evenly distributed over the whole range of subjects in the curriculum, with relatively small opportunity for stress in any one field. The great and competent government service agencies give themselves with increasing measure to consideration of research problems. Presumably this emphasis will grow as the possibility and need of new knowledge become clearer. In general the activities of this group of departments will naturally be distributed over fields in which there is direct demand for the early solution of problems relating to present needs of the community. The laboratories of industrial organizations have come to be among the most powerful agents in use and in support of research. Their activities are directed toward all regions in which materials may conceivably be found which will make for betterment of the industrial product or for efficiency in its use. The only limits set upon this aspect of research are those imposed by the requirement of fidelity to purposes for which the underlying funds are invested. This permits wide range but at the same time imposes restrictions.

Without multiplying illustrations it may be permissible to compare the situation in our Institution with that of the great research enterprises mentioned. One outstanding feature of our foundation is that it has freedom to distribute its support widely or restrict it to any limits which seem desirable. It may take up researches for which a demand of the community happens to be urgent. It may consider those which are of evident importance but may not be needed in human application for a generation. It may select problems rather than subjects and shift its emphasis from time to time as wisdom seems to warrant. In a word, the characteristic of flexibility with reference to problem, place, time, and method of organization, taken with freedom from the requirement of early application of the result, gives an opportunity somewhat different from that of other agencies. It offers the possibility of exploration into unknown regions which may furnish exceptional treasures. That such freedom of opportunity exists means in reality a responsibility for the doing of what may otherwise be difficult to undertake. It suggests that mere paralleling of other researches and failure to select those lines of activity for which we have exceptional advantages would mean evasion of the duty which our freedom imposes.

These considerations make it clear that with all fidelity to undertakings upon which we have embarked, and with the desire to realize accomplishment for all who are connected with this enterprise, we should continue to make the Institution an instrument for use especially in work upon problems concerning the fundamental aspects of knowledge. We should make certain that our contribution is of service by reason of its intrinsic human value, because it may serve to supplement the work of other bodies devoting themselves to the search for new and useful information, and because it aims to interpret that which is fundamental.

Results of Past Year's Work Expressed in Publications.

As desirable as it is to visualize the accomplishments of the Institution during the past year, we realize that our output or contribution is largely of the type which it is not possible to see, to measure, or to weigh with accuracy. Much of the influence of the Institution is exerted through personal discussion of topics with individuals or groups of investigators.

In general our publications furnish that expression of activity which can be defined most easily in the form of a report.

A large number of our most important results go out to the public through regularly established channels of publication, such as the scientific journals and other periodical literature. Papers of this nature written by members of the staff are handled in the same manner as those of other investigators, but in a considerable number of cases, especially those in which it is desired to use articles of exceptional length or with unusually expensive illustrations, the Institution contributes toward publication costs. These papers are thus placed in the well-known channels of publication without undue expense to the journals concerned. Through this medium members of the Institution have presented in the past year approximately 3,300 pages, included in 350 articles occurring in about 90 publications, ranging over the whole field of research from fundamental studies in physics to contributions bearing upon problems of human heredity.

As an illustration of the importance of this concise presentation of the results of our work, the Geophysical Laboratory has issued in the past year 46 articles covering 740 pages, distributed in 12 journals. In this list, those of N. L. Bowen on the behavior of fragments of rock included or enveloped in molten rocks, and papers by E. T. Allen on chemical aspects of volcanic activity, are of special significance in physics and geology. Within the same period Mount Wilson Observatory has issued 101 articles covering 665 pages, distributed in 10 journals and including a range of studies represented by such titles as Dr. Hale's paper on "Invisible Sunspots," in the Proceedings of the National Academy of Sciences, his article on "The Depths of the Universe," in Scribner's Magazine, a paper by Adams and Joy on a method of deriving the distance of the A-type stars, A. S. King's notes on electric-furnace experiments involving ionization phenomena, and Michelson and Pease's "Measurement of the Diameter of α Orionis by the Interferometer."

The publication series handled directly by the Institution this year comprises 24 volumes with a total of 6,605 pages. Most of these contributions are monographic works. In some instances, as in volumes of the Department of Embryology and the Department of Marine Biology, groups of papers on related subjects have been issued under the same cover. These volumes have been issued at a total expense of approximately $95,000.

While it is not possible to make reference here to all of the volumes included in our own series this year, an understanding of the work of the Institution is perhaps given more clearly by this means than by any other method of statement. It is worth noting that among the books in press this year our interest ranges from the work by Barus, on "Displacement Interferometry applied to Acoustics and to Gravitation," a fundamental work in mathematical physics, to studies like those in Smith's monograph on "Gaseous Exchange and Physiological Requirements for Level and Grade Walking," or, in another direction, to the scholarly paper by Lowe and Rand on a recently discovered fragment of Letters of Pliny the Younger, a study in palæography.

As evidence of the progress being made by the Institution, special attention should be called to the issue in 1922 of the final parts of the Pennsylvania volume in the "Index of Economic Material in the Documents of the States of the United States," by Adelaide R. Hasse. This work concludes the series of publications in the Department of Economics and Sociology initiated in 1907, and completes the studies carried on over a period of 18 years. Volume III of the monographic study of the cactus group by Britton and Rose, which has grown out of the investigations of the Desert Laboratory at Tucson, is issued this year just as the fourth and concluding volume is advanced to the press. There is thus rounded out another important unit study conducted under the auspices of the Institution. W. A. Cannon's study of the floras of arid regions in Australia appeared at a time when Dr. Cannon was engaged in a similar investigation of the floras of arid areas in South Africa and India. John F. Hayford's volume on the "Effects of Winds and of Barometric Pressures upon the Great Lakes" represents the completion of data necessary to finish the first part of this work. Under continued support from the Institution, Dr. Hayford is now engaged in the second stage of these studies on an estimate of the stream-flow and evaporation of the Great Lakes. Ralph W. G. Wyckoff's paper, on "The Analytical Expression of the Results of the Theory of Space-Groups," arising from studies in the Geophysical Laboratory, is a contribution of importance appearing at a time when this Laboratory, along with other agencies in the country, is attacking questions relative to the atomic and molecular constitution of crystals with a view to the ultimate bearing of such data on the problem of the structure of matter. J. E. Weaver's work, on "Development and Activities of Roots of Crop Plants," is an unusual study of root variation bearing upon fundamental biological problems and ultimately concerning many questions in practical agriculture of the future. Walter W. Hyde's volume on Victor Monuments is an investigation in the field of classics presenting the results of long-continued study of monuments dedicated to victory. It is one of the important additions to classical research in the past year.

Distribution of Publications.

As a part of the publication program of the Institution, much attention has been given in the course of the past year to consideration of certain modifications in our procedure relating to distribution of volumes issued through the Institution's series. As the works are made available for libraries and for investigators without expectation of profit, our sole object has been so to organize the machinery that we may be certain to reach students and researchers who can use the results to advantage. This object is being attained by very careful consideration of distribution lists, and at the same time by placing the books on sale for those who are not within easy reach of libraries containing the Carnegie Institution's publications but would gladly buy such as they need.

Within the past year we have had in active operation a system by which we have increased the number of libraries and scientific agencies to which our publications are forwarded. This extension has been accomplished by sending partial sets to institutions having only a limited requirement, such as astronomical observatories, biological stations, and chemical laboratories, and by increasing the number of individual copies sent to investigators or students naturally concerned with or interested in the subjects presented. Recently arrangement has been made by which, through submission of special lists prepared by authors, individual copies of new works not to exceed the number of 150 may be made available to distinguished investigators.

By careful distribution it has been possible to reach almost immediately a considerably increased group of individuals, laboratories, and libraries and thus make the results of our investigations touch the scientific work of the world within a comparatively short period. At the same time it has been necessary to guard the lists lest pressure for distribution tend to increase editions to such an extent that it would seem necessary to add to publication investment by taking away from the funds so much needed for development and extension of our researches. The plan now in use seems to find favor by presenting our results quickly and realizing larger dividends on the investment of effort.

Conferences.

As an important means of carrying out the aims of the Institution in several directions, numerous conferences of groups of distinguished investigators have been held during this year. The Committee on Problems of Human Behavior, consisting of E. G. Conklin, Charles B. Davenport, C. E. Seashore, E. L. Thorndike, Clark Wissler, and Robert M.

Yerkes, has held several meetings, in the course of which there has been outlined a series of investigations held to be necessary as a basis of future advance in this subject. Similar conferences on the History of Science, on certain problems of American Archæology, and on many other subjects have advanced the work of the Institution materially and have brought about a closer cooperation with investigators associated with other institutions.

Lectures.

During the past year the Institution has attempted to make some of the results of recent researches available to investigators and interested citizens of Washington through the medium of carefully prepared and illustrated lectures. Two series comprising seven lectures were presented, one in November and the other in March and April. The nature of the first series is illustrated by Dr. Morley's lecture on recent discoveries in the field of early American archæology in Guatemala, and by that of Dr. Arthur L. Day, describing an exhaustive investigation of the recent eruption of Mount Lassen in California. In the second series Dr. L. B. Mendel, a collaborator of the Institution at Yale University, discussed the results of recent work conducted by Doctors Osborne and Mendel in the field of nutrition. Dr. J. N. Rose marked the completion of a monograph on the cactus group by presenting the general results secured in this study of adaptation of a group of plants to the peculiar conditions of semi-arid regions in the western hemisphere. These lectures have served not merely as a means of bringing the general results of research to the scientific public of Washington, but through the accompanying exhibits opportunity has been opened for contact between the investigators and a considerable group of persons especially interested.

Cooperative Research.

A full statement of the researches of the Institution during the past year will be contained in a summary of results in the Year Book covering the year 1922. The account is interesting in every detail. In the list of our publications on page 18 and in the bibliography appended to this report the titles of our published works furnish a striking statement of results. In addition to this exhibit, it is interesting to note in the work of the Institution a tendency to reach toward still more complicated and difficult problems through the medium of cooperative plans.

Although the major part of the work of the Institution is conducted through regularly organized departments, it has also been our pleasure to cooperate with a large number of distinguished investigators situated in universities, special research institutions, government laboratories, museums, and industrial agencies scattered widely over the country. No better illustration of our relation to other work can be found than that shown in the long-standing arrangement with Thomas B. Osborne, of the Connecticut Agricultural Experiment Station, and L. B. Mendel, of Yale University. By this plan Dr. Osborne and Dr. Mendel, considering the problems of nutrition from different points of view but acting in closest cooperation, carry on a series of studies on certain agents in nutrition, including the vitamines, which are at the same time enormously important and extremely elusive. These researches are fundamental scientific work in biology and chemistry. At the same time they are of such importance in nutrition and medicine that the future of much that is critical in these subjects will be dependent upon the work now under way in the several laboratories of this country and Europe giving special attention to this field.

An extremely interesting example of cooperative investigation by a department of the Institution and another important agency in a related field is furnished by studies of the structure of matter undertaken jointly by Mount Wilson Observatory and California Institute of Technology. Investigations in the field of astrophysics carried on with such extraordinary success at Mount Wilson have shown that further advance in astronomical research requires a better understanding of the nature of matter. At the same time it has been clear that the researches in engineering at the California Institute of Technology point constantly toward the need for better understanding of the structure of matter to further advance in engineering knowledge. It has therefore seemed desirable for these two institutions to join forces in this special research and to bring to their assistance a group of the most distinguished men available in the world.

California Institute considers the problem of matter, in its well-equipped physical and chemical laboratories, under the immediate direction of such distinguished investigators as Dr. R. A. Millikan in physics and Dr. A. A. Noyes in chemistry. Mount Wilson Observatory makes use of the sun and stars and observes experiments in progress with the aid of the telescope and the spectroscope. At the same time the laboratories forming a part of the equipment of the Observatory attempt to check, and in a measure reproduce, certain of the effects seen or suggested by study of the sun. Cooperating investigators, such as Professor H. A. Lorentz, of Haarlem, and Professor Paul Epstein, formerly of Leiden, were brought to the

California Institute for conference, while Dr. A. A. Michelson, of Chicago, Dr. Henry Norris Russell, of Princeton, the late Dr. J. C. Kapteyn, of Groningen, Dr. C. G. Abbot, of the Smithsonian Institution, and others cooperating with the Observatory have helped to forward this investigation. In order to further the progress of this work the Carnegie Corporation of New York has made an appropriation of $30,000 a year for five years. By means of this grant Dr. Millikan and Dr. Noyes, of California Institute, are made research associates of the Carnegie Institution, thus making possible more rapid advance in this series of cooperative studies.

In the report of 1921 mention was made of the initiation of investigations in seismology or the study of earthquakes. The problem involves study of the nature of movements of the earth's crust and the expression of these movements in earthquakes, which are both geological and physical phenomena. This series of investigations should ultimately give us a knowledge of earthquakes which will make possible a diminution of their danger by teaching us how it may be met. The study must be approached in such a way as to bring to bear the most advanced views in all the sciences concerned with problems of the earth's crust.

Under the guidance of an able advisory committee consisting of J. A. Anderson, physicist of Mount Wilson Observatory; Ralph Arnold, consulting geologist; W. W. Campbell, Director of Lick Observatory; A. L. Day, Director of Geophysical Laboratory of the Carnegie Institution of Washington; A. C. Lawson, Professor of Geology at the University of California; R. A. Millikan, Director of the Norman Bridge Laboratory of Physics of the California Institute of Technology; Harry Fielding Reid, geologist and physicist of Johns Hopkins University, and Bailey Willis, Professor of Geology at Stanford University, a plan has been worked out for attack on the fundamental questions involved in earthquake study. Marked advance has been made during the past year, and it is most gratifying to report the whole-hearted cooperation of a wide range of the most important agencies in America concerned with the phenomena involved in crustal movements. The United States Geological Survey has undertaken the preparation of detailed maps covering areas of active earthquake movement along the great San Andreas fault or rift in California. The United States Coast and Geodetic Survey has entered upon the work of exact triangulation of certain regions of California which have been affected by earth movements. This survey is conducted with a view to securing detailed information regarding the shift of the earth's crust which has occurred in connection with recent earthquakes. It involves a piece of careful observation such as could be conducted satisfactorily only by an agency like the Coast and Geodetic Survey. The several astronomical observatories of the Pacific Coast are contributing data which will assist in the final determination of questions relating to movements of the earth's crust. Lick Observatory at Mount Hamilton is providing a special instrument for studies in this field. The Hydrographic Office of the Navy Department of the United States is cooperating through arrangement to equip two destroyers with appropriate devices by which they will carry out an elaborate series of soundings along the Pacific Coast. This operation is expected to locate such abrupt changes in the floor of the sea as may indicate the faults or breaks in the earth's crust that have extended from lines of weakness on land into areas beneath the sea. The Bureau of Standards of the Department of Commerce has made important contribution through assistance of experts whose advice has been needed in the construction of new instruments to be used in the detection of delicate earth tremors in earthquake regions. California Institute of Technology, in cooperation with Mount Wilson Observatory, has given both the services of members of the staff and assistance in construction of instruments. The list of contributing agencies should be extended to include the universities of the Pacific Coast and many other bodies desiring to give their assistance in the effort toward solution of the complicated problem.

Dr. Arthur L. Day, Chairman of the Advisory Committee, has visited personally all of the cooperating agencies and has given close attention to the development of this most interesting program of constructive study. Dr. H. O. Wood, Research Associate in Seismology, has been in charge of the field reconnaissance for the Institution. It is important to note that in this study the interests concerned are not merely cooperating—they are advancing knowledge in each of the subjects involved and at the same time promoting an understanding of the earthquake problem.

Future Needs.

In every phase of research undertaken, either directly by the Institution or jointly with other organizations, it would be possible to spend with profit considerable sums beyond those now available; but just as there are certain aspects of knowledge which are relatively more important at one time than at another, so there are various expenditures in investigation which are particularly useful in each stage of the advance of science. Among the varied needs of our departments at this particular moment we still have before us the problem of provision for extending work in high pressure by the Geophysical Laboratory, the opportunity for extension of the laboratory of Mount Wilson Observatory in order to facilitate the researches on the structure of matter in relation to the structure of the universe, and the need for rather rapid development in the land-observation work of the Department of Terrestrial Magnetism. It is also of much importance to us in the near future to expand considerably our program of studies in the field of Middle American Archæology. While it is assumed that the work in any one of these fields may be deferred to another time, we also realize that opportunities depend in large measure upon the presence and availability of those individuals prepared for the work and willing to give themselves whole-heartedly to its furtherance.

Financial Statement for Fiscal Year 1921–1922.

The sources of funds available for expenditure during the fiscal year (including appropriations made by the Trustees December 9, 1921, and revertments and transfers made during the year), the amounts allotted by the Executive Committee during the year, and the balances unallotted at the end of the year, are shown in detail in table A:

A.—*Financial statement for fiscal year ending October 31, 1922.*

	Balances unallotted Oct. 31, 1921.	Trustees' appropriation Dec. 9, 1921.	Revertments and transfers Nov. 1, 1921, to Oct. 31, 1922.	Total available 1922.	Executive Committee allotments 1922.	Transfers by Executive Committee.	Unallotted balances Oct. 31, 1922.
Large Grants:							
Botanical Research	....	$56,500	....	$56,500.00	$56,500.00	....	....
Embryology	....	44,140	$500.00	44,640.00	44,640.00	....	....
Ecological Research	....	32,900	800.00	33,700.00	33,700.00	....	....
Genetics	....	124,005	1,200.00	125,205.00	125,205.00	....	....
Geophysical Laboratory	....	142,044	4,750.00	146,794.00	146,794.00	....	....
Historical Research	....	42,000	700.00	42,700.00	42,700.00	....	....
Marine Biology	....	28,400	2,500.00	30,900.00	30,900.00	....	....
Meridian Astrometry	....	38,532	500.00	39,032.00	39,032.00	....	....
Archæology	....	19,000	500.00	19,500.00	19,500.00	....	....
Nutrition Laboratory	....	46,326	....	46,326.00	46,326.00	....	....
Mt. Wilson Observatory	....	232,168	5,400.00	237,568.00	237,568.00	....	....
Terrestrial Magnetism	....	173,609	500.00	174,109.00	174,109.00	....	....
Minor Grants	$4,885.79	193,000	5,630.04	203,515.83	188,019.49	$13,396.34	$2,100.00
Publications	9,331.32	94,500	22,379.44	126,210.76	121,331.03	....	4,879.13
Administration	....	60,000	....	60,000.00	60,000.00	....	....
Insurance Fund	....	11,000	....	11,000.00	11,000.00	....	....
Pension Fund	....	40,000	....	40,000.00	40.000,00	....	....
General Contingent Fund	....	45,000	27,220.29	72,220.29	....	69,970.29	2,250.00
	14,217.11	1,423,124	72,579.77	1,509,920.88	1,417,324.52	83,366.63	9,229.13

Receipts and Expenditures of the Institution to Date.

The aggregates of receipts from interest on endowment, from interest on bond investments and bank deposits, from sales of publications, from refunds on grants, and from miscellaneous sources, for each year since the foundation of the Institution, are shown by table B; the grand total of these to date is $21,831,544.38.

B.—*Aggregates of financial receipts.*

Year ending Oct. 31.	Interest on endowment.	Interest on bonds and bank deposits.	Sales of publications.	Refunds on grants.	Miscellaneous items.	Total.
1902	$250,000.00	$9.70	....	....	$1,825.52	$251,835.22
1903	500,000.00	5,867.10	$2,286.16	....	101.57	508,254.83
1904	500,000.00	33,004.26	2,436.07	$999.03	....	536,439.36
1905	500,000.00	25,698.59	3,038.95	200.94	150.00	529,088.48
1906	500,000.00	27,304.47	4,349.68	2,395.25	19.44	534,068.84
1907	500,000.00	22,934.05	6,026.10	2,708.56	15.22	531,683.93
1908	550,000.00	17,761.55	7,877.51	25.68	48,034.14	623,698.88
1909	600,000.00	14,707.67	11,182.07	2,351.48	103,564.92	731,806.14
1910	600,000.00	10,422.78	10,470.25	1,319.29	54,732.45	676,944.73
1911	975,000.00	14,517.63	10,892.26	4,236.87	923.16	1,005,569.97
1912	1,100,000.00	31,118.41	11,496.13	1,658.88	96,035.01	1,240,308.42
1913	1,103,355.00	46,315.60	12,208.66	3,227.53	345,769.95	1,510,876.74
1914	1,105,084.17	59,298.63	11,402.40	7,819.70	577,305.77	1,760,910.67
1915	1,100,375.00	67,888.31	10,297.79	8,322.87	28,162.79	1,215,046.76
1916	1,100,375.00	83,626.38	12,544.16	1,450.12	153,204.40	1,351,200.06
1917	1,100,408.75	100,702.60	11,921.35	32,950.22	179,611.97	1,425,594.89
1918	1,110,427.45	120,464.02	9,921.00	39,833.23	255,354.60	1,536,000.30
1919	1,112,441.25	138,700.73	12,837.58	53,549.98	214,498.99	1,532,028.53
1920	1,112,441.25	159,559.03	18,393.79	4,088.63	176,249.81	1,470,732.51
1921	1,112,441.25	170,211.22	16,684.51	4,068.69	210,518.96	1,513,924.63
1922	1,112,504.52	175,021.09	14,081.84	9,395.66	34,527.38	1,345,530.49
Total	17,644,853.64	1,325,133.82	200,348.26	180,602.61	*2,480,606.05	21,831,544.38

*Of this amount, $1,444,335 came from the sale of bonds in 1908, 1909, 1910, 1912, 1913, 1914, 1915, 1916, 1917, 1918, and 1921; $51,265.74 from the Colburn Estate in 1916; and $930,000 from the Carnegie Corporation of New York in 1917, 1918, 1919, 1920, 1921, and 1922.

The purposes for which funds have been appropriated by the Board of Trustees of the Institution may be classified under five heads: (1) Investments in bonds; (2) large projects; (3) minor and special projects; (4) publications; (5) administration. Table C shows the actual expenditures under these heads for each year since the foundation of the Institution:

C.—*Aggregates of Expenditures*

Year ending Oct. 31.	Purchase of bonds.	Large projects.	Minor and special projects.	Publications.	Administration.	Total.
1902	....	....	$4,500.00	....	$27,513.00	$32,013.00
1903	$100,475.00	....	137,564.17	$938.53	43,627.66	282,605.36
1904	196,159.72	$49,848.46	217,383.73	11,590.82	36,967.15	511,949.88
1905	51,937.50	269,940.79	149,843.55	21,822.97	37,208.92	530,753.73
1906	63,015.09	381,972.37	93,176.26	42,431.19	42,621.89	623,216.80
1907	2,000.00	500,548.58	90,176.14	63,804.42	46,005.25	702,534.39
1908	68,209.80	448,404.65	61,282.11	49,991.55	48,274.90	676,163.01
1909	116,756.26	495,021.30	70,813.69	41,577.48	45,292.21	769,460.94
1910	57,889.15	427,941.40	83,464.63	49,067.00	44,011.61	662,373.79
1911	51,921.79	454,609.75	72,048.80	37,580.17	45,455.80	661,616.31
1912	436,276.03	519,673.94	103,241.73	44,054.80	43,791.13	1,147,037.63
1913	666,428.03	698,337.03	110,083.06	53,171.59	43,552.89	1,571,572.60
1914	861,864.23	817,894.52	107,507.55	44,670.55	44,159.54	1,876,096.39
1915	206,203.21	770,488.58	109,569.37	46,698.56	48,224.04	1,181,183.76
1916	473,702.70	638,281.41	99,401.26	73,733.38	49,454.08	1,334,572.83
1917	502,254.05	695,813.07	100,746.13	62,884.61	48,766.29	1,410,464.15
1918	528,565.55	693,780.00	170,470.74	44,394.83	49,118.76	1,486,329.88
1919	438,960.29	845,123.82	203,810.84	68,964.23	55,742.83	1,612,602.01
1920	464,279.57	876,437.28	159,633.49	95,933.10	68,739.90	1,665,023.34
1921	109,390.25	981,186.46	171,895.22	81,388.33	58,730.11	1,402,590.37
1922	50,431.05	975,149.20	192,325.46	96,227.01	56,405.15	1,370,537.87
Total	5,446,719.27	11,540,452.61	2,508,937.93	1,030,925.12	983,663.11	21,510,698.04

Investments in Property.

On account of site for and construction of the Administration Building of the Institution, and on account of real estate, buildings, and equipments of departmental establishments, the following sums have been expended since the foundation of the Institution:

D.—*Real estate and equipment, original cost.*

Administration:		
Building, site, and equipment		$339,591.06
Department of Botanical Research (Sept. 30, 1922):		
Buildings and grounds	$54,705.41	
Laboratory and library	26,597.41	
Operating appliances	11,580.20	
		92,883.02
Ecological Research (Dec. 31, 1921):		
Building, Laboratory	4,547.00	
Library, operating	2,069.88	
		6,616.88
Department of Embryology (Sept. 30, 1922):		
Library	1,069.17	
Laboratory	7,622.85	
Administration	3,514.35	
		12,206.37
Department of Genetics (Sept. 30, 1922):		
Buildings, grounds, field	264,714.69	
Operating	18,792.08	
Laboratory apparatus	11,044.42	
Library	20,723.83	
Archives	45,484.24	
		360,759.26
		812,056.59

D.—*Real estate and equipment, original cost*—cont'd.

Brought forward		$812,056.59
Geophysical Laboratory (Sept. 30, 1922):		
Building, library, operating appliances	$186,473.29	
Laboratory apparatus	87,492.71	
Shop equipment	11,197.73	
Department of Historical Research (Sept. 30, 1922):		285,163.73
Office	3,138.92	
Library	4,367.54	
Department of Marine Biology (Sept. 30, 1922):		7,506.46
Vessels	30,930.43	
Buildings, docks, furniture, and library	12,130.86	
Apparatus and instruments	9,322.55	
Department of Meridian Astronometry (Sept. 30, 1922):		52,383.84
Apparatus and instruments	3,257.34	
Operating	3,560.60	
Nutrition Laboratory (Sept. 30, 1922):		6,817.94
Building, office, and shop	123,093.26	
Laboratory apparatus	26,260.11	
Mount Wilson Observatory (Aug. 31, 1922):		149,353.37
Buildings, grounds, road, and telephone line	193,500.74	
Shop equipment	39,281.84	
Instruments	473,854.63	
Furniture and operating appliances	153,921.43	
Hooker 100-inch reflector	590,210.76	
Department of Terrestrial Magnetism (Sept. 30, 1922):		1,450,769.40
Building, site, and office	203,373.84	
Vessel and survey equipment	166,243.68	
Instruments, laboratory, and shop equipment	102,474.83	
		472,092.35
		3,236,143.68

Sales of Publications and Value of those on hand.

Table E shows the amounts received from subscriptions to the Index Medicus, from sales of Year Books, and from sales of all other publications for each year since the foundation of the Institution.

E.—*Table showing sales of publications.*

Year.	Index Medicus.	Year Book.	Miscellaneous books.
1903	$2,256.91	$29.25	....
1904	2,370.47	52.85	$12.75
1905	2,562.76	44.75	431.44
1906	2,970.56	37.60	1,341.52
1907	3,676.71	56.50	2,292.89
1908	3,406.19	99.65	4,371.67
1909	4,821.85	73.01	6,287.21
1910	4,470.50	100.70	5,899.05
1911	4,440.21	85.50	6,366.55
1912	4,652.14	61.65	6,782.34
1913	4,992.02	75.95	7,140.69
1914	5,079.16	49.65	6,273.59
1915	5,010.21	47.60	5,239.98
1916	4,382.19	46.60	8,115.37
1917	4,616.21	51.55	7,253.59
1918	4,324.29	21.10	5,575.61
1919	4,267.95	93.30	8,476.33
1920	5,451.86	40.50	12,901.43
1921	6,277.32	50.55	10,356.64
1922	5,774.59	59.25	8,248.00
Total	85,804.10	1,177.51	113,366.65

At the end of the fiscal year there are on hand 91,618 volumes of miscellaneous publications and Year Books, having a sale value of $273,748.25; also 33,280 numbers of the Index Medicus, having a value of $19,980. The total value of publications on hand is therefore $293,728.25. It is fitting to add that since the foundation of the Institution there have been distributed, chiefly by gifts to libraries and to authors, but to a noteworthy extent also by sales, 242,196 volumes of publications of the Institution.

Growth and Extent of Institution's Publications.

The data furnished in table F are of statistical interest in respect to the work of publication of the Institution. 466 volumes, which embrace a total of 130,766 pages of printed matter, have thus far been issued.

F.—*Table showing number of volumes, number of pages (octavo and quarto), and totals of pages of publications issued by the Institution for each year and for the twenty years from 1902 to 1922.*

Year.	Number of volumes issued.	Number of octavo pages.	Number of quarto pages.	Total number of pages.
1902......	3	46	....	46
1903......	3	1,667	....	1,667
1904......	11	2,843	34	2,877
1905......	21	3,783	1,445	5,228
1906......	19	3,166	1,288	4,454
1907......	38	6,284	3,428	9,712
1908......	28	4,843	2,485	7,328
1909......	19	3,695	1,212	4,907
1910......	29	3,274	4,831	8,105
1911......	30	5,062	1,670	6,732
1912......	23	3,981	2,044	6,025
1913......	29	6,605	2,752	9,357
1914......	23	4,978	1,934	6,912
1915......	23	4,686	1,466	6,152
1916......	35	9,478	2,430	11,908
1917......	21	4,464	2,691	7,155
1918......	17	3,073	1,220	4,193
1919......	29	5,834	2,431	8,265
1920......	23	3,962	3,710	7,672
1921......	18	4,068	1,398	5,466
1922......	24	4,566	2,039	6,605
Total...	466	90,358	40,408	130,766

Publications Authorized and Issued during the Year.

The publication of 19 volumes has been authorized by the Executive Committee during the year, at an aggregate estimated cost of $79,000. The following list gives the titles and names of authors of the publications issued; it includes 24 volumes, with an aggregate of 4,566 octavo pages and 2,039 quarto pages. Thirteen additional volumes are now in press.

G.—*List of publications issued during the year ending October 31, 1922.*

Year Book, No. 20, 1921. Octavo, xxii+475 pages, 1 plate, 10 figures.

Index Medicus, Third Series. Vol. 1, 1921. Octavo, 1,242 pages.

Tenth edition of an illustrated pamphlet on the Scope and Organization of the Carnegie Institution of Washington. Octavo, 58 pages, 1 plate, 2 maps, 33 figures.

No. 85. Hasse, Adelaide R. Index of Economic Material in the Documents of the States of the United States. Quarto.
  Pennsylvania, Part II, F to Railroads, pages 811–1,479.
  Pennsylvania, Part III, Rainfall to Z, pages 1,481–1,711.

No. 175. Vol. IV. Bauer, L. A., in collaboration with J. A. Fleming, H. W. Fisk, and W. J. Peters. Land Magnetic Observations, 1914–1920, and Special Reports by J. A. Fleming, H. W. Fisk, and S. J. Barnett. (Researches of the Department of Terrestrial Magnetism.) Quarto, vi+475 pages, 9 plates, 17 figures.

No. 215A. Johnson, E. R., T. W. Van Metre, G. G. Huebner, and D. S. Hanchett, with an introductory note by H. W. Farnam. History of Domestic and Foreign Commerce of the United States. Second edition. Reproduced by photography and issued in one volume. Octavo, 785 pages, 10 maps.

No. 248. Britton, N. L., and J. N. Rose. The Cactaceae: Descriptions and Illustrations of Plants of the Cactus Family. Quarto, in 4 volumes.
  Vol. III. vii+255 pages, 24 plates, 250 figures.

No. 268. Hyde, Walter W. Olympic Victor Monuments and Greek Athletic Art. Octavo, xix+406 pages, 33 plates, 80 figures.

No. 273. Contributions to Embryology, Nos. 47 and 48. Vol. X. Quarto. This book contains the following papers:
  Evans, Herbert McLean, and Katharine J. Scott.—On the Differential Reaction to Vital Dyes of the Two Great Groups of Connective-Tissue Cells. (Contribution No. 47.) 55 pages, 11 plates.
  Macklin, Charles C.—The Skull of a Human Fetus of 43 Millimeters Greatest Length. (Contribution No. 48.) 48 pages, 5 plates.

No. 293. Treadwell, A. L. Leodicidæ of the West Indian Region. (Paper from the Department of Marine Biology. Vol. XV.) Quarto, iv+131 pp., 9 pls., 467 text-figs.

No. 304. Lowe, E. A., and E. K. Rand. A Sixth-Century Fragment of the Letters of Pliny the Younger. Quarto, vi+67 pages, 20 plates.

No. 306. Contributions to the Geology and Palæontology of the West Indies. Octavo, iv+122 pp., 18 plates, 6 figs. This book contains the following papers:
  Jackson, Robert T.—Fossil Echini of the West Indies.
  Vaughan, Thomas Wayland.—The Stratigraphic Significance of the Species of the West Indian Fossil Echini.

No. 308. Cannon, W. A. Plant Habits and Habitats in the Arid Portions of South Australia. Octavo, viii+139 pp., 32 plates, 31 figures.

No. 309. Smith, Henry Monmouth. Gaseous Exchange and Physiological Requirements for Level and Grade Walking. Octavo, viii+310 pages, 1 plate, 42 figures.

No. 310. Barus, Carl. Displacement Interferometry Applied to Acoustics and to Gravitation. Octavo, viii+149 pages, 183 figures.

No. 311. Cushman, Joseph A. Shallow-water Foraminifera of the Tortugas Region. (Paper from the Department of Marine Biology of the Carnegie Institution of Washington, Vol. XVII.) Octavo, 85 pages, 14 plates, 1 map, 8 figures.

No. 314. Loftfield, J. V. G. The Behavior of Stomata. Octavo, 104 pp., 16 pls., 54 figs.

No. 316. Weaver, J. E., F. C. Jean, and J. W. Crist. Development and Activities of Roots of Crop Plants. Octavo, vi+116 pages, 14 plates, 42 figures.

No. 317. Hayford, John F. Effects of Winds and of Barometric Pressures upon the Great Lakes. Octavo, v+133 pages, 16 plates.

No. 318. Wyckoff, Ralph W. G. The Analytical Expression of the Results of the Theory of Space Groups. Octavo, vii+180 pages, 34 figures.

No. 319. Cooper, W. S. The Broad-Sclerophyll Vegetation of California: An Ecological Study of the Chaparral and its Related Communities. Octavo, 124 pp., 21 pls., 43 figs.

No. 320. Castle, W. E. Genetic Studies of Rabbits and Rats. Octavo, 55 pp., 2 pls., 7 figs.

No. 321. Case, E. C. New Reptiles and Stegocephalians from the Upper Triassic of Western Texas. Quarto, 84 pages, 14 plates, 33 figures.

Alfred G. Mayor

IN MEMORIAM.

Alfred Goldsborough Mayor.

It is with a deep sense of loss to science and to the Institution that record is made of the death of Dr. Alfred Goldsborough Mayor, Director of the Department of Marine Biology, a distinguished contributor to the advancement of science in this field. Sustained by an exceptional enthusiasm and devotion to science, Dr. Mayor continued his work at the Tortugas Laboratory practically to the last moments of his life, which ended on June 24, 1922.

Dr. Mayor was born at Frederick, Maryland, April 16, 1868. At the age of twenty-one years he graduated with the degree of mechanical engineer from Stevens Institute of Technology. In recognition of his studies in zoology he received the degree of Doctor of Science from Harvard University in 1897. Following in the footsteps of his father, a distinguished professor of physical sciences, he taught physics for periods of two years at Clark University and at the University of Kansas. Later he was associated with Alexander Agassiz in developing the Museum of Comparative Zoology at Harvard and accompanied Agassiz on various scientific expeditions to the Bahamas, to Australia, and to the islands of the South Pacific.

In 1900 Dr. Mayor was appointed Curator of Natural Sciences in the museum of the Brooklyn Institute, and in 1904 he joined the staff of the Carnegie Institution of Washington to superintend the erection of the Marine Biological Laboratory at Tortugas and to complete the organization of this department.

Through the medium of the Tortugas Laboratory and with the assistance of contacts formed by many expeditions conducted in the tropics, Dr. Mayor was able to outline an organization and carry through a great number of fundamental investigations in the field of marine biology. He came thus to see realized many of the ideals arising from his scientific philosophy. His personal researches concerned a wide range of types of marine invertebrates. A long list of his publications in this field appears in the reports of the Institution, many of his own papers being included in our published contributions. Dr. Mayor was a scholar of unusual originality and versatility. He had advantage of the instincts of the engineer and investigator combined with a splendid general scientific training. These qualifications were of large value to him in directing the activities of the Department of Marine Biology and made possible some of the most significant work, such as is illustrated by the application of physical and chemical experimentation to distinctly biological problems.

In his personal characteristics Dr. Mayor was distinguished by the ability to give himself unreservedly to support and development of the problems of others. His tact and persuasiveness enabled him to deal effectively with a great variety of difficult conditions encountered in his work in the laboratory and in the field. By reason of desire to give his thought to the advancement of work carried on by other individuals, the organization of the Department of Marine Biology developed along lines somewhat different from those of many other groups of investigators. In spite of the great significance of the researches conducted by his many associates in other institutions, the splendid personality and enthusiasm of the Director furnished so large a part of the element of cohesion in the department that the removal of Dr. Mayor presents a problem of great difficulty in considering the possible future of research in this field.

Dr. Mayor is taken from us as a director and organizer and we feel deeply the loss of his immediate personal support and judgment; yet we should not forget that his influence as a constructive student continues as a stimulus operating through the infinite series of contacts which connect the work of others in this time and other times with those movements originating in his life and personality.

Jacobus Cornelius Kapteyn.

It is with great regret that we make record also of the death of another distinguished contributor to science, Professor J. C. Kapteyn, Research Associate in Astronomy with the Carnegie Institution, for many years professor of astronomy and mechanics at the University of Groningen, and more recently connected with the Leiden Observatory. Dr. Kapteyn's death occurred on June 18, 1922, shortly after his return to Holland from a visit to the United States. Dr. Kapteyn was for fifteen years associated with the work of Mount Wilson Observatory and visited this country frequently for the purpose of collaboration with the members of our staff. He was a source of inspiration to all those who came in contact with him in his researches. Many important investigations at Mount Wilson Observatory owe their success in some measure to the influence of Dr. Kapteyn's pioneer studies on stellar motions, and in the future development of fundamental research in this field his work will always have an important part.

APPENDIX.

BIBLIOGRAPHY OF PUBLICATIONS RELATING TO WORK OF INVESTIGATORS, ASSOCIATES, AND COLLABORATORS.

Under this heading it is sought to include titles of all publications proceeding from work done under the auspices of the Carnegie Institution of Washington, exclusive of the regular publications. A list of the latter which have appeared during the year will be found in the President's Report (p. 18).

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REPORT OF THE EXECUTIVE COMMITTEE.

REPORT OF THE EXECUTIVE COMMITTEE.

To the Trustees of the Carnegie Institution of Washington:

Gentlemen: Article V, Section 3, of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication; and Article VI, Section 3, provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for fiscal year ending Oct. 31, 1922.

During this year the Executive Committee held eight meetings, printed reports of which have been mailed to each Trustee.

Upon adjournment of the meeting of the Board of Trustees of December 9, 1921, the members of the Executive Committee met and organized by the reelection of Mr. Walcott as Chairman for 1922, and by voting that the Administrative Secretary of the Institution act as secretary of the Committee for the same period.

The President's report gives in detail the results of the work of the Institution for the fiscal year 1921–22, together with itemized financial statements for the same period and a summary of receipts and expenditures of the Institution to date. The President also submits a report and outline of suggested appropriations for the year 1923. The Executive Committee hereby approves the report and recommendations of the President, upon the basis of which additional recommendations respecting appropriations for the year 1923 were authorized by the Committee at its meeting of this date.

The Board of Trustees, at its meeting of December 9, 1921, appointed the American Audit Company to audit the accounts of the Institution for the fiscal year ending October 31, 1922. The report of the auditor, including a balance-sheet showing the assets and liabilities of the Institution on October 31, 1922, is herewith submitted as a part of the report of the Executive Committee.

There is also submitted a statement of receipts and disbursements since the organization of the Institution on January 28, 1902.

No vacancies exist in the membership of the Board nor in any of its committees.

Charles D. Walcott, *Chairman.*
Cleveland H. Dodge.
John C. Merriam.
Wm. Barclay Parsons.
Stewart Paton.
Henry S. Pritchett.
Elihu Root.
Henry White.

December 1, 1922.

Aggregate Receipts and Disbursements from Organization, January 28, 1902, to October 31, 1922.

RECEIPTS.		
Interest:		
Endowment	[a]$17,936,107.13	
Reserve Fund (Cr. to R. F.)	631,661.31	
Reserve Fund Cr. to Income	259,948.64	
Insurance Fund	94,738.60	
Colburn Fund (Cr. C. F.)	26,822.14	
Colburn Fund Cr. to Income	3,543.77	
Pension Fund	17,165.87	
		$18,969,987.46
Colburn Fund		52,015.74
Sales of Publications:		
Index Medicus	85,804.10	
Year Book	1,177.51	
Miscellaneous	113,366.65	
		200,348.26
Revertments:		
Grants and Unallotted Publication	179,859.31	
Administration	11,411.28	
Unappropriated Fund	22,415.54	
		213,686.13
Miscellaneous:		
Carnegie Corporation of N. Y.		
C. I. of W. $750,000.		
Nat'l R. C. 150,000.		
Special 30,000.		
	930,000.00	
Insurance Fund	5,372.53	
Pension Fund	7,968.44	
Sale of paper	6,556.45	
		949,897.42
Redemption and Sale of Bonds		1,445,609.37
		21,831,544.38

DISBURSEMENTS		
Investment:		
Securities	$5,127,993.49	
Collection charges	8,810.09	
Administration Building and Site	309,915.69	
		$5,446,719.27
Pension Fund		89,232.88
Insurance		24,770.94
Grants:		
Large	11,540,452.61	
Minor	2,244,934.11	
		13,785,386.72
Publication		[c]1,030,925.12
National Research Council		150,000.00
Administration:		
Trustees	[b]54,821.97	
Executive Committee	33,962.88	
Advisory Committees:		
Honoraria 1902–07	11,860.00	
Travel and subsistence	4,367.41	
Salaries	592,427.49	
Shipping publications	[c]56,567.24	
Rent, surety, telephone	33,815,86	
Postage, express	24,576.86	
Printing	[c,d]64,283.92	
Office expenses	33,720.93	
Equipment	17,664.39	
Building and grounds:		
Supplies, janitor	33,568.88	
Fuel, light, water	13,575.38	
Contingent	1,457.92	
Organization expenses (1902)	6,991.98	
		983,663.11
		21,510,698.04
Cash in Banks		320,846.34
		21,831,544.38

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[a] Including interest from Income and Building Fund bonds.

[b] Travel and subsistence in connection with official meetings.

[c] Year Books and shipping publications carried under Administration to January 1, 1921, and thereafter under Publication.

[d] Including Year Books published prior to January 1921.

REPORT OF AUDITORS.

WASHINGTON, D. C., *November 20, 1922.*

TO THE BOARD OF TRUSTEES,
Carnegie Institution of Washington,
Washington, D. C.

DEAR SIRS: We have audited the books and records of the Carnegie Institution of Washington for the year ended October 31, 1922. We did not audit the books of the various departments, as this is done by the Bursar and Assistant Bursar.

The income from investments and other sources has been duly accounted for and disbursements were supported by proper vouchers.

We counted the cash on hand, and the cash in banks was verified with certificates from the despositaries.

The securities representing the investments were exhibited to us.

We certify that the balance-sheet, the schedules of securities and real estate and equipment, and the statement of receipts and disbursements printed on pages 40 to 45 of the Year Book for 1922 are in accordance with the books.

Respectfully submitted.

THE AMERICAN AUDIT COMPANY,
By C. R. CRANMER, *Resident Manager.*

[SEAL.]
Approved:
F. W. LAFRENTZ,
President.
Attest:
W. H. PICKETT,
Ass't Secretary.

Balance Sheet, October 31, 1922.

ASSETS.

Investments (interest-bearing securities):			
Endowment		$22,119,722.55	
Colburn Fund		104,092.97	
Reserve Fund		3,099,729.44	
Insurance Fund		342,793.99	
Harriman Fund		300,000.00	
Pension Fund		123,082.41	$26,089,421.36
Cash—			
Endowment, Colburn and Reserve Fund, awaiting investment	$935.36		
Insurance Fund, for current purposes	24,573.04		
Pension Fund, for current purposes	11,625.34	37,133.74	26,126,555.10
Property Account:			
Real Estate and Equipment at original cost—			
Division of Administration		339,591.06	
Departments of Research		2,896,552.62	3,236,143.68
			29,362,698.78
Current Assets:			
Cash—			
Investment accounts	283,712.60		
Petty cash and stamps	400.00	284,112.60	
Income estimated for the year 1922—			
Balance uncollected		144,117.88	
Publications and Paper—		428,230.48	
Books on hand at sale price	293,728.25		
Printing paper in stock for future publications	17,785.75		
	311,514.00		
Outstanding Accounts—			
For publications sold	1,923.99	313,437.99	
			741,668.47
			30,104,367.25

LIABILITIES.

Endowment and Other Funds:			
Endowment		$22,120,000.00	
Colburn Fund		104,605.80	
Reserve Fund		3,099,874.52	
Insurance Fund		367,367.03	
Pension Fund		134,707.75	
Harriman Fund		483,671.75	$26,310,226.85
Income Invested in Property			3,052,471.93
			29,362,698.78
Current Liabilities:			
Large Grants	$188,671.48		
Minor Grants	89,460.23		
Publications	68,013.04		
Administration	17,738.73		
		363,883.48	
General Contingent Fund		2,250.00	
Unappropriated Balance		62,097.00	428,230.48
Value of Publications, Paper, and Invoices			313,437.99
			30,104,367.25

Receipts and Disbursements or the Year Ending October 31, 1922.

RECEIPTS.		
Interest from:		
Endowment—		
Bonds	$1,112,441.24	
Bank balance	8,121.15	
		$1,120,562.39
Reserve Fund—		
Bonds	140,688.33	
Bank balance	24.82	
		140,713.15
Insurance Fund—		
Bonds	14,673.08	
Bank balance	579.98	
		15,253.06
Colburn Fund—		
Bonds	5,151.63	
Bank balance	45.20	
		5,196.83
Pension Fund—		
Bonds	5,482.36	
Bank balance	317.82	
		5,800.18
Sales of Publications:		
Index Medicus	5,774.59	
Year Book	59.25	
Miscellaneous books	8,248.00	
		14,081.84
Revertments:		
Grants and Unallotted, Publication	8,652.36	
Unappropriated Fund	413.55	
Administration	329.75	
		9,395.66
Miscellaneous:		
Carnegie Corp. of N. Y.	30,000.00	
Pension Fund	4,379.47	
Insurance Fund	112.58	
Sale of paper	35.33	
		34,527.38
		1,345,530.49
Balance, Oct. 31, 1921		345,853.72
		1,691,384.21

DISBURSEMENTS.		
Investment:		
Securities	$50,203.11	
Collection charges	227.94	
Pension Fund:		$50,431.05
Annuity contribution		33,895.59
Insurance Fund		2,500.00
Grants:		
Large	975,149.20	
Minor	155,929.87	
Publication:		1,131,079.07
General Publications	74,808.94	
Catalogues, etc	1,794.75	
Shipping expenses	7,065.97	
Division of Publications	12,557.35	
Administration:		96,227.01
Trustees	3,237.14	
Executive Committee	1,605.50	
Salaries	39,493.34	
Surety, rent, telephone	739.74	
Postage, express	1,018.06	
Printing, paper	2,703.29	
Office expenses	2,715.19	
Equipment	471.69	
Building and grounds—		
Supplies, janitors	2,646.23	
Fuel, light, water	821.38	
Contingent	953.59	
		56,405.15
Cash in Banks:		1,370,537.87
Uninvested Principal:		
Endowment	277.45	
Reserve Fund	145.08	
Colburn Fund	512.83	
Pension Fund	11,625.34	
Insurance Fund	24,573.04	
	37,133.74	
Investment Accounts	283,712.60	
		320,846.34
		1,691,384.21

Schedule of Securities.

Par Value.	SECURITIES.	Investment Value.	Total.
	Endowment.		
$21,200,000	U. S. Steel Corporation, Registered 50-year 5% Gold Bonds, Series A, B, C, D, E, F, due April 1, 1951	$21,200,000.00	
175,000	Chicago, Milwaukee & Puget Sound Railway Company, First Mortgage 4% Gold Bonds, due January 1, 1949	159,268.00	
14,000	Chicago, Milwaukee & St. Paul Railway Company, General Mortgage 4½% Gold Bonds, due May 1, 1989	13,953.75	
325,000	Lehigh & Lake Erie Railroad Company, First Mortgage 4½% 50-year Gold Bonds, due March 1, 1957	331,568.30	
237,000	New York City 4½% Registered Bonds, due March 1, 1963	253,557.50	
150,000	South & North Alabama Railroad Company, Consolidated Mortgage 5% Bonds, due August 1, 1936	160,875.00	
500	United States of America Third Liberty Loan	500.00	
			$22,119,722.55
	Colburn Fund.		
20,000	Acker, Merrall & Condit Company, Debenture 6% Bonds	13,600.00	
4,000	Chicago, Milwaukee & St. Paul Railway Company, General Mortgage 4½% Bonds. due 1989	4,070.00	
4,000	Oregon Short Line Railroad Company, Consolidated First Mortgage 5% Guaranteed Gold Bonds, due 1946	3,910.00	
8,000	Park & Tilford Company, Sinking Fund Debenture 6% Bonds	6,400.00	
50,000	Pennsylvania Railroad Company, General Mortgage 4½% Bonds, due June 1, 1965	51,062.50	
42,000	Pittsburg, Shawmut & Northern Railroad, First Mortgage 4% Bonds, due February 1, 1952	4,200.00	
10,650	United States of America Second Liberty Loan Converted 4¼s	9,922.67	
5,500	United States of America Third Liberty Loan of 1918	5,291.16	
3,100	United States of America Fourth Liberty Loan of 1918	3,036.64	
2,600	United States of America Victory Liberty Loan of 1919	2,600.00	
			104,092.97
	Harriman Fund.		
100,000	Southern Pacific Company, San Francisco Terminal, First Mortgage 4% Bonds, due 1950	100,000.00	
200,000	Chicago, Burlington & Quincy R. R. Co., Illinois Division, 4% Bonds, due 1949	200,000.00	
			300,000.00
22,551,350	*Carried forward*		22,523,815.52

Schedule of Securities—continued.

Par Value.	SECURITIES.	Investment Value.	Total.
$22,551,350	*Brought forward*		$22,523,815.52
	Reserve Fund.		
50,000	American Telephone & Telegraph Company, Collateral Trust 4% Bonds, due 1929	$45,500.00	
96,000	American Telephone & Telegraph Company, 4½% Convertible Bonds	99,456.25	
100,000	Baltimore & Ohio Railroad Company, General and Refunding 5% Bonds, due 1995	102,375.00	
50,000	Central Pacific Railway Company, First Refunding Mortgage 4% Registered Gold Bonds, due 1949	48,250.00	
150,000	Chicago, Burlington & Quincy Railroad Company, General Mortgage, 4% Bonds, due March 1, 1958	141,263.75	
15,000	Chicago, Milwaukee & St. Paul Railway Company, General Mortgage 4½% Gold Bonds, due May 1, 1989	14,925.00	
120,000	Chicago and North-Western General Mortgage 3½% Bonds, due November 1, 1987.	100,300.00	
155,000	General Electric, 5% Gold Debenture Bonds.	158,213.47	
48,000	Great Northern Railway Company, First and Refunding Mortgage 4¼% Bonds, due 1961	48,109.25	
100,000	Illinois Central Railroad Company, Refunding 4% Bonds, due 1955	89,668.75	
280,000	Interborough Rapid Transit Company, First Refunding Mortgage 5% Bonds, due 1966.	276,701.00	
50,000	Lake Shore & Michigan Southern Railway Company, Registered 25-year 4% Gold Bonds, due September 1, 1928	47,000.00	
50,000	Long Island Railroad Company, Refunding Mortgage 4% Bonds, due 1949	48,285.00	
50,000	New York, Westchester & Boston Railway Company, First Mortgage 4½% Bonds, due 1946	49,187.50	
50,000	Northern Pacific Railway Company, Refunding and Improvement, 6% Bonds, due 2047	48,250.00	
50,000	Northern Pacific Railway Co., General Lien Railway and Land Grant 3% Bonds, due Jan. 1, 2047	33,101.25	
2,000	Oregon Short Line Railroad Co., Consolidated First Mortgage, 5% Guaranteed Gold Bonds, due 1946	1,955.00	
50,000	Oregon-Washington Railroad & Navigation Company, First and Refunding 4% Mortgage Bonds, due 1961	46,375.00	
30,000	Pennsylvania Railroad Company, General Mortgage 4½% Bonds, due June 1, 1965	29,837.50	
101,000	Pennsylvania Railroad Company, Consolidated Mortgage, 4½% Bonds, due Aug. 1, 1960	105,608.12	
100,000	Southern Pacific Railroad First Refunding Mortgage, 4% Bonds, due 1955	92,148.75	
140,000	Union Pacific Railroad Co. First Lien and Refunding 4% Bonds, due June 1, 2008	128,722.50	
112,500	United States Liberty Loan—1st Converted 4¼s—due 1947	112,500.00	
384,300	United States of America Liberty Loan of 1917—2d Converted	349,286.85	
419,500	United States of America Third Liberty Loan of 1918	404,728.20	
364,000	United States of America Fourth Liberty Loan of 1918	357,181.30	
120,800	United States of America Victory Liberty Loan of 1919	120,800.00	3,099,729.44
25,789,450			25,623,544.96

Schedule of Securities—continued.

Par Value.	SECURITIES.	Investment Value.	Total.
$25,789,450	*Brought forward*		$25,623,544.96
	Insurance Fund.		
28,000	American Telephone & Telegraph Company, 4½% Convertible Bonds	28,978.00	
50,000	Atchison, Topeka & Santa Fe Railway Company, General Mortgage 100-year, 4% Registered Gold Bonds, due 1995	50,056.25	
25,000	Bell Telephone Company of Canada, Debenture 5% Bonds, due April 1, 1925	24,760.00	
30,000	Chicago, Burlington & Quincy Railroad Company, General Mortgage 4% Bonds, due March 1, 1958	28,237.50	
1,000	Chicago, Milwaukee & St. Paul Railway Company, General Mortgage 4½% Gold Bonds, due May 1, 1989	995.00	
21,000	Great Northern Railway First and Refunding 4¼% Bonds, due 1961	20,944.00	
21,000	Illinois Central Railroad Company, Refunding Mortgage 4% Bonds, due November 1, 1955	19,008.75	
25,000	Oregon Short Line Railroad Company, Consolidated First Mortgage 5% Guaranteed Gold Bonds, due 1946	24,468.25	
24,000	Pennsylvania Railroad Company, Consolidated Mortgage 4½% Bonds, due August 1, 1960	25,095.01	
26,700	United States of America Second Liberty Loan Converted 4¼s	23,722.33	
63,500	United States of America Third Liberty Loan of 1918	61,128.90	
3,000	United States of America Fourth Liberty Loan of 1918	3,000.00	
32,400	United States of America Victory Liberty Loan of 1919	32,400.00	
			342,793.99
	Pension Fund.		
20,000	Oregon Short Line Railroad Co., Consolidated First Mortgage, 5% Guaranteed Gold Bonds, due 1946	19,550.00	
50,000	United States of America Victory Liberty Loan of 1919	50,000.00	
61,350	United States of America Second Liberty Loan Converted 4¼s	53,532.41	
			123,082.41
26,271,400			26,089,421.36

Real Estate and Equipment, Original Cost.

Administration:		
Building, site, and equipment		$339,591.06
Department of Botanical Research (September 30, 1922):		
Buildings and grounds	$54,705.41	
Laboratory and library	26,597.41	
Operating appliances	11,580.20	
		92,883.02
Ecological Research (December 31, 1921):		
Building, Laboratory	4,547.00	
Library, Operating	2,069.88	
		6,616.88
Department of Embryology (September 30, 1922):		
Library	1,069.17	
Laboratory	7,622.85	
Administration	3,514.35	
		12,206.37
Department of Genetics (September 30, 1922):		
Buildings, grounds, field	264,714.69	
Operating	18,792.08	
Laboratory apparatus	11,044.42	
Library	20,723.83	
Archives	45,484.24	
		360,759.26
Geophysical Laboratory (September 30, 1922):		
Building, library, operating appliances	186,473.29	
Laboratory apparatus	87,492.71	
Shop equipment	11,197.73	
		285,163.73
Department of Historical Research (September 30, 1922):		
Office	3,138.92	
Library	4,367.54	
		7,506.46
Department of Marine Biology (September 30, 1922):		
Vessels	30,930.43	
Buildings, docks, furniture, and library	12,130.86	
Apparatus and instruments	9,322.55	
		52,383.84
Department of Meridian Astrometry (September 30, 1922):		
Apparatus and instruments	3,257.34	
Operating	3,560.60	
		6,817.94
Nutrition Laboratory (September 30, 1922):		
Building, office, and shop	123,093.26	
Laboratory apparatus	26,260.11	
		149,353.37
Mount Wilson Observatory (August 31, 1922):		
Buildings, grounds, road, and telephone line	193,500.74	
Shop equipment	39,281.84	
Instruments	473,854.63	
Furniture and operating appliances	153,921.43	
Hooker 100-inch reflector	590,210.76	
		1,450,769.40
Department of Terrestrial Magnetism (September 30, 1922):		
Building, site, and office	203,373.84	
Vessel and survey equipment	166,243.68	
Instruments, laboratory, and shop equipment	102,474.83	
		472,092.35
		3,236,143.68

REPORTS ON INVESTIGATIONS AND PROJECTS

The following reports and abstracts of reports show the progress of investigations carried on during the year, including not only those authorized for 1922, but others on which work has been continued from prior years. Reports of Directors of Departments are given first, followed by reports of recipients of grants for other investigations, the latter arranged according to subjects.

DEPARTMENT OF BOTANICAL RESEARCH.[1]

D. T. MacDougal, Director.

Progress has been made in the principal problems to which the resources of the Department and the energy of the members of the staff and collaborators are directed as detailed in the following paragraphs:

PHOTOSYNTHESIS AND METABOLISM.

Photosynthesis, by H. A. Spoehr.

In the autumn of 1919 experimental investigations were begun to establish definitely whether photosynthesis is a process intimately associated with the vital activity of the plant and thus dependent upon the general protoplasmic metabolism or whether photosynthesis can proceed independently of these activities and simply contributes material essential to the oxidative catabolism and to growth. It was argued that if a direct interdependence exists between the photosynthetic and catabolic activities of the plant, it is to be expected that factors influencing the respiration would then also affect the photosynthetic activity. Therefore, an extensive investigation of the respiratory activity of leaves was undertaken with a view of establishing the more essential factors which determine the rate of the oxidative breakdown of the carbohydrate fuel material and the relation which these bear to the photosynthetic activity. These investigations have been brought to a conclusion and have been submitted for publication.

Experimental Methods.

Extensive preliminary investigations were made to test out the various principles and methods of determining the rates of respiration and of photosynthesis of land plants. In view of the great complexity of these processes and the large number of factors which must be taken into consideration, the greatest care must be exercised to avoid spurious results, so that the long time which has been put upon these preliminary studies has proved to have been fully warranted.

For the purposes of these investigations a highly accurate method was developed, based upon the differential determination of carbon dioxid. This gas is absorbed in solutions of barium hydroxide and the concentration of the latter determined by means of the electrical conductivity. Suitable absorption tubes, sedimentation vessels, and electrolytic cells have been devised and constructed. The wide range of experimental conditions over which these investigations have been carried, entailing the determination of relatively large as well as of very small quantities of carbon dioxid, necessitated careful checking of the degree of accuracy of these methods for each set of conditions. The electrolytic method of carbon-dioxid determination offers far greater flexibility than any other method, in that almost any required degree of accuracy can be obtained for widely different experimental conditions by a rational adjustment of (1) the concentration and quantity of the absorbing barium-hydroxide solution, (2) the length of periods of a single determination, (3) the rate of gas flow, (4) the concentration of the carbon dioxid in the gas stream, and (5) the resistance of the electrolytic cells employed. Similarly, for any series of experiments all of these factors must be properly adjusted to each other in order to determine the degree of accuracy of the set conditions and so as to avoid attempting to attain results which the accuracy of the entire system does not warrant. The work on these methods is being continued, and several new pieces of apparatus have been designed and are being tested.

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[1] Situated at Tucson, Arizona, and Carmel, California.

Experimental Material.

The use of entire plants, while desirable in many ways, was found utterly impractical when striving for any degree of precision. It is clearly evident that further insight into the mechanism of the processes of respiration and photosynthesis can be gained only from experimentation, that is, by rigorous control of the external conditions as well as some of the internal factors influencing these processes. Therefore, the studies have been carried out primarily with excised leaves and entire plants have been used only when it was essential to establish the relation of the leaves to the rest of the plant. Besides many other advantages, this method offers the only satisfactory means of feeding to leaves substances the behavior of which it is desired to study.

It was found that in many plants the gaseous exchange of the photosynthetic and respiratory processes is complicated through structural peculiarities of the leaf which make the interpretation of observational data very difficult. For this reason only thin leaves were used. Moreover, experience proved that a rational interpretation of these processes can not be attained without considerable knowledge of the internal condition of the leaf. Much attention has therefore been devoted to the elaboration of accurate analytical methods and all of the conclusions are based upon the analyses of the carbohydrate and proteinaceous components of the leaves. It has become clearly evident that without such data a rational interpretation of measurements of the rates of respiration is quite impossible.

Considerable attention was also given to establishing the length of time necessary to obtain a true respiration curve. Special apparatus was constructed for the automatic control of the carbon-dioxid absorption vessels. This made possible the carrying out of many experiments, each of about 100 hours' duration with a continuous respiration record.

The Carbohydrate-Amino Acid Relation in the Respiration of Leaves, by H. A. Spoehr and J. M. McGee.

For some time it has been evident that the rate of respiration, even under carefully controlled external conditions, is greatly influenced by certain internal factors. Besides the carbohydrates, nitrogen compounds which may be present in relatively small amounts have been found to be of profound influence. In order to avoid much of the confusion arising from the consideration of a carbohydrate-nitrogen ratio, special attention was given to the influence of amino-acids in the respiratory process. Thus, it was found that the stimulating effect of amino-acids on the respiratory activity and carbohydrate consumption of leaves appears to be closely akin to the specific dynamic effect of proteins and amino-acids, as has been worked out by Rubner, Lusk, and others in the higher animals. The same general effect has now been determined in plants with a number of different amino-acids.

Various attempts have been made to determine more precisely the nature of this phenomenon. It was thought highly probable that the amino-acids affected the sugars directly, exerting an isomerizing action by converting the more stable sugars into those which are more easily broken down. However, all experiments directed to establish such an isomerizing action of the amino-acids on various hexose sugars yielded negative results. The recent work of Sherman and his coworkers on the influence of amino-acids on certain enzyme activity offers a new means of approach to this fundamental problem.

Attention has also been given to a consideration of the function of leaf proteins. In the plant cell the carbohydrates and fats serve as the fundamental sources of energy in respiration. The nitrogen derivatives, with which the plant deals most economically, as proteinaceous compounds constitute an essential portion of the medium in which the chemical reactions of the cell occur. The proteins are of fundamental importance because of their ability to yield amino-acids which influence the functioning of enzymes and catalysts and by virtue of their amphoteric character can control the condition of solution within the cell. The course of change of the nitrogenous components of leaves in relation to variations in carbohydrate-content and consumption were followed by analytical methods through a wide range of natural and experimental conditions. This work is serving as a basis of information concerning the respiratory activity of leaves and has already proved its fundamental value in its application to the photosynthesis problem.

The two internal factors determining the rate of respiration, namely, the supply of carbohydrates and the free amino-acids, are both influenced by light. The amino-acid content increases in the dark, light apparently reversing the reaction, so that proteins are synthesized from amino-acids under the latter conditions; while the carbohydrate-content decreases in the dark, and through photosynthesis increases in the light. A change in either component affects the rate of respiration. Thus, a plant with high carbohydrate-content, after exposure to light, shows for a certain period a decreased rate of respiration, and light can be regarded as, under circumstances, inhibiting respiratory activity. In view of the fact that determinations of photosynthesis are based upon differential determinations of carbon dioxid, it is absolutely essential that these conditions relative to the amino-acid and carbohydrate-content, as well as to the respiration, be established before any conclusions be drawn as to the rate of carbon-dioxid fixation. This has been the principal purpose of the respiration studies.

Mechanism of Photosynthesis and the Internal Factor, by H. A. Spoehr.

Evidence has been accumulating rapidly that in the photosynthetic process there is an essential internal factor which operates independently of those clearly recognizable factors, temperature, light intensity, partial pressure of CO_2, and water-content of the leaf. This internal factor has been variously described by different workers; its existence has been established through several methods. These include (*a*) the relation of the chlorophyll pigments to photosynthetic activity (Willstaetter and Stoll), (*b*) effect of anesthetics and poisons on respiration and photosynthesis (O. Warburg), (*c*) dependence of photosynthesis on certain oxygen pressure, (*d*) determination of photosynthetic efficiency (O. Warburg's Nutzeffekt). These and many older investigations are in accord with the theory of a direct interdependence of photosynthesis and respiration which has been developed on the basis of work carried out in this laboratory during the last two years.

There seem to be two distinct sets of reactions which go to make up the photosynthetic process. These two reactions are of unmistakably different character and type. Under certain experimental conditions one of these reactions is predominantly noticeable; under other circumstances, the properties of the second reaction are more apparent. One of these reactions is photochemical, the other is an ordinary chemical reaction. The object of the present researches is to establish the nature of these reactions and to determine in what manner these two sets of reactions are coupled. It has, moreover, been possible to differentiate these two steps of the photosynthetic process experimentally and to apply the reasoning of recent theoretical physical developments to each of the steps. The conception of a possible primary photolysis of carbonic acid in the living organism has not only received no experimental support but from the work of Willstaetter and Stoll and that carried out in this laboratory becomes highly improbable. Moreover, by the calculations of E. Warburg on the basis of the Einstein law of photochemical equivalent, the two simple reactions $CO_2 = C + O_2$ and $2\ CO_2 = 2\ CO + O_2$ are excluded as photochemical primary reactions.

Photosynthesis is not a simple photolysis of carbonic acid. There is required an acceptor which reacts with the product of the primary light-reaction. This acceptor is not carbonic acid, but is formed in a series of reactions into which CO_2 enters. The product of the primary light-reaction acts on the acceptor to produce the secondary reaction. We have then in photosynthesis first of all the formation of the acceptor and (1) the primary light-reaction and (2) the secondary reaction. It is in the first of these reactions, the formation of the photochemical acceptor, that the enzymatic or respiration process enters, and this forms the basis of the interdependence of photosynthesis and respiration. The reaction producing the acceptor is of the same chemical type and apparently associated with respiratory activity. These studies have established a quantitative relationship between the rates of respiration and photosynthesis. All factors which have been found to affect photosynthesis through disturbances in the vital or protoplasmic activity of the plant exert their influence through the respiratory process. Thus carbon dioxid is made the acceptor in a photo-chemical reaction by being first altered in this process of acceptor-formation, which step is in the nature of a coupled reaction.

In view of the fact that the rate of photosynthesis follows so closely the rate of respiration, the theory is proposed that these two series of reactions, proceeding in opposite directions, are actually interdependent. This interdependence may be either on the basis that the energy released in respiration actually aids or is essential to one of the two reactions constituting the photosynthetic process, or the relation may be based upon the action of an enzyme or catalyst which functions in both reactions. Into which of the two reactions of photosynthesis the respiratory process meshes is still uncertain. However, the contribution in energy which respiration could make would naturally be relatively small and, from a thermodynamic consideration, the greatest lift in energy must be in the photochemical reaction.

The chemical reactions involved in these two processes are, in the case of respiration, a series of oxidations, and in photosynthesis a general reversal thereof in the reduction of CO_2 to C. There is much evidence to support the conclusion that reduction and oxidation reactions in living organisms are intimately connected and dependent upon the same or very closely allied agents. It is therefore as yet impossible to state whether the acceptor formation in photosynthesis is directly the result of respiratory activity or whether these two actions are brought about by the same agents or conditions, and that what affects one activity also affects the other. On the basis of these experiments and theoretical deductions the investigations on photosynthesis are being extended in several directions.

Temperature Coefficients and Efficiency of Photosynthesis, by H. A. Spoehr and J. M. McGee.

One of the methods which is now being utilized to differentiate between the two reactions in photosynthesis and to establish their properties is the determination of the temperature coefficients. It has been found that much of the confusion which has arisen in the interpretation of former work on this subject has been due to inadequately controlled experimental conditions and to a misinterpretation of van 't Hoff's law. Moreover. as the photosynthetic activity is so decidedly influenced by the internal factor, consistent results can not be expected without taking this factor into consideration. This can be done only on the basis of adequate and accurate knowledge of the respiratory activity gained from separate experiments and analyses. Conditions have been worked out where either one of the two reactions of photosynthesis determines the rate of the entire process. By thus carefully selecting precisely controlled conditions, it is hoped that the leaf will reveal some of the important characteristics of these two reactions. In view of the complexity of the reactions and the many factors involved, conclusions can be drawn only from a very extensive series of experiments. Special apparatus has been constructed in the constant-temperature chambers at Carmel which permits very accurate control of all the factors involved in these studies. The ultimate object of these investigations is to gather experimental data which will permit the application of the recent developments of photochemistry and energetics to the problem of photosynthesis.

A determination of the fundamental question of the efficiency of the process also depends upon these results. By means of Nernst's third law the free energy of the photosynthesis process has been calculated by Warburg:

$$\underset{(0.0003\text{ atmos.})}{6\,CO_2} + \underset{(\text{liquid})}{6\,H_2O} = \underset{(\text{solid})}{C_6H_{12}O_6} + \underset{(0.2\text{ atmos.})}{6O_2} - 690{,}000\text{ cal.}$$

that is, to reduce 1 mol of CO_2 at least 150,000 calories are required. Photosynthetic efficiency must be taken as the ratio of chemical work gained to absorbed radiant energy. Various attempts have been made to determine this quantity. However, no consistent results have been obtained, there being large and apparently irregular variations. This has been substantiated by the careful experiments of Mueller and Warburg, who found wide variations in the photosynthetic efficiency for light of a given wave-length under constant conditions of temperature, carbon-dioxid pressure, and light-intensity. It is now quite evident that these variations are attributable to the influence of the internal factor, and the work will be continued to determine the photosynthetic efficiency with this factor taken into consideration.

Carbohydrate Metabolism of Leaves, by H. A. Spoehr.

Carbohydrates are the first products of photosynthesis. From experience as well as on the basis of theoretical considerations, the sugars containing 6 carbon atoms are of foremost importance as the primary products of photosynthesis. This is also the form into which most sugars are converted before they are utilized by most of the higher plants and the higher animals. It is, however, a remarkable fact that of the 32 theoretically possible hexose sugars only 4 are generally found distributed in nature. All of these sugars are stereoisomers and differ only in the internal structure of the molecule. It is apparent that there are in the photosynthetic process asymmetric forces at work which regularly produce these highly asymmetric molecules. That these forces are equally important to the life of an organism as the chemical affinities was already recognized by Pasteur.

In view of the recently developed conceptions of the structure of atoms these forces take on a new significance. The influences producing an asymmetric molecule are apparently of the nature of magnetism, with the same attractive and repellent forces. Since the development of the theories of magnetism on the basis of rotating electrons by de Haas and Einstein the problem of the asymmetric forces is thrown into the domain of electrical charge and is to be ascribed probably to the nature of the carbon atom itself. In the chemistry of symmetrical substances the product of a reaction is solely dependent upon the chemical forces of the reacting molecules. But in the reactions of asymmetric substances the products are also dependent upon the influence exerted on each other by the reacting asymmetric molecules. These asymmetric forces can act either to accelerate or retard the chemical reaction. Chemical work on asymmetric syntheses, which was begun several years ago, is being continued from the point of view of the electron theory of valence.

This work is being pursued primarily in order to apply the principles of asymmetric synthesis to the photosynthesis problem. It now appears that, (1) either all of the possible hexose sugars are formed in the photosynthetic process and are then converted into the three sugars commonly found in plants, or (2) there are forces which permit the formation of only those sugars existing in the plant. Experimental evidence is being sought in both directions.

1. The situation of the first possibility is as follows: It has not been possible to detect even very small amounts of hexose sugars other than those ordinarily found. As yet nothing is known of the behavior of these other sugars (e. g., the levo sugars) in the higher plants. These substances can be obtained only through very laborious synthetic chemical manipulation. The work of synthesizing these sugars has been under way for some time and some of the products have already been obtained. A study of the behavior of these substances will then be undertaken with living organisms in order to determine the fate of these sugars as to a possible transformation into other sugars and in the general metabolism. Furthermore, there have been prepared synthetically very pure products of formose (from formaldehyde) and glycerose

which are mixtures of many of the possible sugars. A careful study of the behavior of these substances in the chlorophyllous leaf is now in progress.

2. If there are asymmetric forces which direct the course of sugar synthesis in the photosynthetic process, these are either (*a*) physical forces or conditions which can be regarded as part of the environment of the plant, or (*b*) the influence is within the plant mechanism. As to the first possibility, it has been impossible to attain a permanent asymmetric synthesis through any agency applied from without. The synthesis of formose through the condensation of formaldehyde is greatly accelerated, it was found, by light. However, no orienting effect by polarized light on the formaldehyde molecules could be accomplished. This was also found to be the case with the highly polarized sky-light. The second possibility of an asymmetric force within the leaf has been followed in several directions. It is well known that an asymmetric molecule extends an asymmetric influence in its chemical reactions. The effect of a number of asymmetric substances on the condensation of formaldehyde to formose has been extensively investigated. These asymmetric substances include many which are found as normal constituents of leaves. However, thus far no definite asymmetric synthesis has been obtained. These investigations are being continued and have recently been extended to include a study of the mutual transformation of sugars in the plant.

Influence of Various Sugars on Respiration, by H. A. Spoehr and J. M. McGee.

As the first step in the investigations of the behavior of various sugars in chlorophyllous leaves, a study was made of the influence of those sugars on respiratory activity. This work was done in conjunction with that on the carbohydrate-amino-acid relation in the respiration of leaves. The same methods and apparatus were used, thus assuring a high degree of accuracy. Moreover, the rates of respiration were determined with the leaves in the dark for 95 hours. It was found that periods of this length were essential in order to arrive at a fair estimate of the respiratory work of the leaves. In all experiments the leaves were also analyzed for carbohydrates and amino-acids.

When dextrose is fed to leaves, the carbohydrate-content is maintained or increases. However, the rate of respiration is not dependent on the amount of available carbohydrates alone. If the amino-acid content of the leaves is low, even a very high carbohydrate-content will not result in high respiratory activity. Conversely, a high respiratory activity may be attained with high amino-acid and low carbohydrate content. When both factors are high, the respiration reaches a maximum. For this reason, in comparing the effect of different sugars, it is essential that the amino-acid content of the leaves be also taken into consideration. It appears, however, that under all conditions dextrose produces the highest rates of respiration. With leaves which are given dextrose the stimulating action of amino-acids is very noticeable.

When leaves are fed sucrose the effect on the rate of respiration is in general of the same nature but less marked. Thus, also, the influence of amino-acids on leaves given sucrose is not as intense as when dextrose is given.

The purely chemical experiments of Nef as well as the physiological investigations of Lusk on higher animals point to the conclusion that levulose is more easily oxidized than any of the other hexose sugars. Among the lower plants there is a great diversity in the capacity for using this sugar. The experiments with leaves of the higher plants indicate that, unlike the animal, levulose is not the most easily oxidized sugar. Under comparable conditions, levulose produces a far lower respiratory activity than either d-glucose or sucrose. Moreover, with levulose no stimulating effect of the amino-acids could be detected; in fact, in many cases when amino-acids, together with levulose, are given to the leaves, the respiration rates are lower than when this sugar is given alone.

The effect of d-mannose on higher plants has for some time been in dispute. All of the experiments with this sugar not only showed no toxic effects, but produced a relatively high rate of respiration. Similarly, the leaves given d-mannose were appreciably stimulated in their respiration by amino-acids.

In these investigations on the equilibrium and use of the various carbohydrates the important points center about the glucose-levulose ratio. With starch and sucrose as the form in which carbohydrates are most generally stored in the plant, it is of fundamental importance to know first of all to what extent each of the splitting products of starch and sucrose can serve the plant in its metabolic economy and whether glucose and levulose are interconvertible in the plant. Also, it is essential to know to what extent the proportion of these two sugars controls the formation of starch or sucrose. As the latter two substances represent the most common form in which carbohydrates are used commercially, this information has a very direct bearing on a number of branches of agriculture.

The continuation of these experiments is directed to establish the role which each of these sugars plays in different processes of the plant and the conditions governing starch and sucrose formation.

These investigations, together with those on the carbohydrate-amino-acid relation, offer the key to the interpretation of observations of long standing which have never been adequately explained. Brown and Morris first reported that the diastatic activity of leaves increased when these are kept in the dark. The leaf, deprived of photosynthetic activity, is thus assured an ample supply of hexose sugars for respiration while the store of starch lasts. This has commonly been given the teleological explanation that as the leaf needs more sugar the starved protoplasm elaborates the means of obtaining it. On the basis of the fact that leaves kept in the dark increase in amino-acids, together with the observation of Sherman and his coworkers of the accelerating influence of amino-acids on diastatic activity, the phenomenon of increased diastatic activity of leaves in the dark receives a rational explanation. Thus, an increase in diastatic activity under these conditions simply means that the amino-acids in the leaves had increased and thereby produced conditions which are favorable to diastatic activity.

Determination of Small Amounts of Various Sugars present in Leaves, by H. A. Spoehr and F. A. Cajori.

In the first stages of the investigations on the carbohydrate metabolism and equilibrium in plants, it was recognized that advance in this field is largely dependent upon the development of analytical methods. The analysis of plant material presents many extraordinary difficulties not encountered in material of animal origin. This has necessitated the working out of a number of new methods adapted to plant material. One of these, described in publication No. 287 of the Institution, has continued to yield very satisfactory results for the determination of reducing sugars.

It now was necessary to determine quantitatively small amounts of glucose, levulose, sucrose, and maltose. It soon became evident that any method dependent upon the use of the polariscope was not sufficiently accurate. The cause of this was that the various sugars are present in only very small amounts and a very slight error in the reading of the angle of rotation resulted in serious errors in the final results. This was further complicated by the facts that most of the solutions used are more or less highly colored, increasing the difficulty just mentioned; and that in leaf extracts there may be other optically active substances, through slight errors caused by varying amounts of inorganic salts. It was therefore imperative that some other method be developed.

Accordingly, Dr. F. A. Cajori of Stanford University spent three months at the Laboratory and worked out the principle of a method which is applicable to the present needs. This method is based upon the fact that aldoses, glucose, mannose, galactose, and maltose are oxidized to the corresponding monobasic acids, while levulose and sucrose are not affected. The use of this principle, together with the copper method already referred to, answers the requirements of determining the small amounts of the various sugars found in leaves. The many conflicting reports regarding the accuracy of the iodine method, it was found, were due to the fact that only under precisely controlled conditions does the reaction proceed according to the formula

$$RCHO+2I+H_2O=RCHOOH+2HI.$$

Dr. Cajori has worked out the proper conditions for each of the sugars encountered in the leaf. He has established the degree of alkalinity, the length of time required for complete oxidation of each sugar, and the most favorable temperature for the reaction. Since each sugar behaves differently, it was necessary to work out conditions which would cover all cases without allowing the reaction to go too far. The oxidation of the sugar is carried out in alkaline solution with an excess of iodine at 25°. The mixture is then neutralized with sulphuric acid and the excess iodine titrated back with standard sodium thiosulphate.

It was first established that levulose is not oxidized by iodine; this is the case even when the solution contains 15 per cent of sodium carbonate and is allowed to stand for 90 minutes at 25°. In oxidizing the aldoses it is desirable to avoid the effect of the alkali on the sugar. Sodium carbonate has no enolization action on the ordinary hexoses and it was found that the concentration of this salt can vary within wide limits without changing the rate of oxidation. In the final method oxidations are carried out in a solution of 0.8 to 1.5 per cent sodium carbonate.

It was impossible to get the oxidation of glucose to proceed in neutral solution even in the presence of iron salts. Glucose is oxidized by iodine in the presence of disodium hydrogen phosphate, but the rate of oxidation is much slower than with sodium carbonate. There is no indication of any specific action of the phosphate and the rate of oxidation seems to be a matter of the hydroxyl-ion concentration.

There is always a slight loss of iodine independent of the oxidation reaction; this amount must be determined in a blank experiment in each determination and allowed for. Three times the amount of iodine necessary to oxidize the sugar is required to give a complete reaction. Within limits, dilution of the iodine has no effect on the rate or completeness of the oxidation; as long as there is sufficient excess of iodine present the concentration of the solution is not significant. Because of the tendency of free iodine to escape the temperatures of the reacting mixture above 25° are to be avoided. It was also found desirable to carry out the oxidations in the dark, as avoidance of light is as important as temperature-control on the stability of the iodine solution. The iodine solution was standardized in terms of glucose by means of the U. S. Bureau of Standards glucose, dried in vacuum over phosphorus pentoxide.

The oxidation of glucose in the presence of small or large amounts of levulose proceeds without being influenced by the levulose. This is also true when sucrose is used in place of levulose. This method can be used to determine the amount of glucose and sucrose present together, by oxidizing the glucose present before and after inversion. In order to avoid the action of the acid on levulose in the course of inversion, a series of experiments established that the best conditions for this is 1 per cent hydrochloric acid at 60° for 2 hours.

Finally, iodine oxidizes glucose but not levulose; cupric hydroxide oxidizes both sugars. The use of these two reagents with the method previously worked out, and the present one, enables a determination to be made of glucose, levulose, and sucrose when these three sugars occur together. The copper solution must be standardized for both glucose and levulose; the factor to convert levulose, calculated as glucose, was found to be 0.9033. Thus, in such a mixture the following results were obtained:

	Found per cubic centimeter.	Present per cubic centimeter.
	mg.	*mg.*
Glucose...........	1.235	1.259
Levulose..........	0.594	0.565
Sucrose...........	1.599	1.549

Maltose can also be brought into the scheme of analysis, though it is found much less frequently in plants. Sucrose is hydrolyzed five times more quickly than is this sugar. Under the conditions used to invert sucrose there is no effect on the maltose, so that advantage is taken of this fact in the analytical separation of these two sugars. Maltose is best hydrolyzed with maltase. However, some difficulty has been encountered in the use of this enzyme, so that this portion of the method is still to be perfected. The calibration of the copper solution for maltose has shown that 1 c. c. Benedict solution equals 3.583 mg. maltose, and to convert maltose, calculated as glucose, the factor 1.5052 should be used.

GROWTH AND PERMEABILITY.

Dendrographic Records of Growth in Trees, by D. T. MacDougal.

The studies of the factors influencing growth in trees have been continued. The records of the changes in diameter associated with growth in 12 trees were recorded in 1921 and of 17 in 1922. There are now available the records of 70 seasons' growth which were obtained by the use of the dendrograph on a total of 20 species for one or more seasons. A continuous tracing of the changes in diameter of Monterey pine No. 1 for four years beginning September 1918 is available and more attention has been devoted to this species than any other.

The individuals selected for the observations represent also certain conditions of soil and exposure. Experiments in variations in water-supply, effects of girdling, and decapitation, etc., have been made. With the numerous improvements in design of the dendrograph by which the accuracy of this instrument has been increased, it has been found possible to differentiate the variations in the woody cylinder from those of the extreme outer layer composed of the cambium, bast, and bark. Correlations between the variations of the trunk and of the stomatal action and accompanying variations in transpiration have been established.

The behavior of a walnut (*Juglans major*) in its native habitat at 7,000 feet, in the Santa Catalina Mountains, Arizona, and at the Coastal Laboratory near sea-level, has been studied.

The dendrograph has been successfully adapted to the measurement of the variations in volume of the giant cactus (*Carnegiea gigantea*) of Arizona, bringing to light some striking changes in volume which appear to be due to different agencies from those which are operative in a woody trunk.

The Artificial Cell with Biocolloidal Membranes, by D. T. MacDougal.

The type of artificial cell described in the report of this Department for 1921 (see pages 57–59) has been used extensively in a study of the nature of the exchanges between the living cell and its environment. In the earlier use of the cell, and in obtaining the results which have been published previously, the cell was constructed with outer clay walls with the pores of such a size that when filled with calcium chloride at 0.01 M a negative osmose followed.

The researches in hand require measurements of the possible action of the actual constituents of the walls and outer layers of the plant cell. It was therefore important to use material of approximately the same character in the cell. The improved type was constructed as follows: A double thickness extraction-thimble (Schleicher and Schöll or Whatman) 33 by 80 mm. was taken to represent the denser skeletal part of the cell-wall. This was fitted with a cork stopper through which were passed two glass tubes. One tube was 3 cm. in length, 8 mm. internal diameter, and served as a filling tube. The other tube was 8 cm. long, 5 mm. in diameter, and the free end was bent at right angles and pointed, serving as a delivery tube. The thimble was dipped in agar (4 per cent solution) at 90° to 100° C. until the wall was thoroughly infiltrated. When this had cooled it was dipped in commercial alcohol which precipitated the agar in the form of granules held in the meshes and on the surface of the cellulose fibers of the wall. After remaining in the alcohol 15 minutes the preparation was removed and dried in the air-current from an electric fan, which required about 3 hours.

The thimbles were now filled with a 3 per cent solution of lecithin in water and allowed to stand 10 minutes. The lipin would be carried into the interstices in the fiber and between the granules and locked there by the beginning hydration of the agar particles and of the fibers of cellulose. The lecithin was now drained out and the cell was ready for being fitted with whatever plasmatic lining was desired. If agar alone was used, a few cubic centimeters of a liquid solution was run in through the filling-tube at about 60° C. and the cell revolved slowly in the hand to allow it to set as a uniform layer. The resulting total arrangement was one which colloidally represented the arrangement of the living cell with such fidelity as to furnish some very important information.

Such a cell showed a much higher rate of activity with relation to its vacuolar contents than the earlier cell with a clay wall. As constructed, the new type had a capacity of 15 to 20 c. c., or about half that of the original cell. The earlier type of cell with the clay walls did not reach its maximum activity with whatever contents until the second, third, or fourth day at 15° C. The improved cell became fully functional (compared with the living cell) much earlier and at a time determined by the nature of the contents. This was taken to be due entirely to the character of the outer wall.

The outer wall of the new cell was made up of aggregated agar particles infiltrated with lecithin. When placed in water, both the lecithin and the agar hydrate very slowly, and the agar at room temperatures does not liquefy. It follows, therefore, that when cells were filled with sugar solutions, for example, this hydration would proceed very slowly. So long as the particles retained full individuality the layer which they form would be highly permeable. Sugar-filled cells (10 per cent), therefore, showed but little activity on the first day, but the swelling of the agar proceeded at such rate that on the second and third days a layer or membrane of some density would be completed and then water would pass more rapidly than sugar with a resultant endosmose. Increase in the volume of the contents was followed, of course, by an outflow through the delivery-tube which was measured directly.

The chief value of such a cell is that its action shows the effects of the salts which are being absorbed on the colloidal material of the walls and membranes of cells. This may be illustrated by the following results of the action of cells with various contents when immersed in water:

Contents.	Osmotic value, calculated, mercury.	Actual endosmose, 24 hours.
KCl 0.01M	28	5.9 c.c.
NaCl 0.01M	27	4.8 c.c.
$CaCl_2$ 0.01M	40	1.2 c.c.
Sucrose 10 p. ct.	52 mm. mercury.	4.8 c.c.

It is obvious that the osmosis resulting in these cells was not proportional to that which might have ensued if the walls of the cells had been constructed of membranes such as parchment or collodion, which would not have been affected by the substance in the filling solution. Their ions, however, exert a marked effect on the colloidal condition of the colloids of the wall of this cell, producing changes which modify its permeability in a very marked manner.

Effect of Lipins in Interchanges between Cells and the Environment,

by D. T. MacDougal.

Accumulating evidence, including biochemical tests of the occurrence of lipins or phosphatides in cells, microscopic and ultramicroscopic examinations of plasma and wall, and the use of reagents which would liquefy such lipins, supports the conclusion that the external layer of protoplasm is essentially a deposit of these fatty substances. Not only are the lipins abundant in this part of the cell, but strands are found to extend into the protoplasm and into the wall.

An experimental consideration of these new aspects of the cell was made by osmotic tests with the artificial cell described in the report of this department for 1921, and has been perfected further, as noted in the present report. The results thus obtained have been correlated with measurements of hydration tests of biocolloids and with the swellings of living and dried cell-masses in solutions identical with those used in the artificial cells.

The incorporation of lecithin representing the lipins in a biocolloid representing protoplasm did not materially affect the water-holding capacity of the mass. When this material, however, formed a layer on the outside the absorption of water from solutions of various salts was modified in an important manner. That such a layer is present in the living cell is demonstrated by the fact that when saponin as a substance which will displace or liquefy lipin is used, the cell becomes highly permeable and salts readily pass into and out of it.

That the lipin may exert a decided influence on permeability is shown by the results obtained with the artificial cell. This material is less permeable to salts than such pentosans as agar in a jelly form, so that when a layer of it is placed between the agar plasma of a cell and the outer wall, the osmotic effect is increased.

The immersion of a living cell in water is followed by the absorption of water until the full capacity of the protoplasm is reached and the cell attains the greatest possible size under the restraining influence of the wall. If the water in which the cell is immersed contains substances in solution which penetrate the wall and make it and the outer layer of protoplasm more permeable, the amount of swelling shown will be reduced. In accordance with these facts, a cell which will show an increase of 40 per cent of its volume in distilled water will not increase more than one-fourth of this amount in a 0.005 M solution of saponin. Potassium hydroxide, which liquefies fatty substances, exerts a similar effect on swelling at 0.01 N.

The hydration, swelling, or absorption of water by living and dead cells are of a kind which might be displayed by a colloidal mass surrounded by a layer of lipin or fatty material and inclosed in an extensible and highly permeable wall.

Permeability in Plant Cells, by D. T. MacDougal.

Two main features may be taken to determine the permeability of the wall, membranes, or outer layers of protoplasts: the chemical composition of these layers and the changes which may be induced by the substances which pass through them. The weight of evidence now points to the predominance of the pentosans and of the lipins in the outer layers of plant cells, in which the proteins may play only a subordinate part. The material of both groups of substances may be arranged in such condition as to allow the passage of both fat-soluble and water-soluble material. Some writers are disposed to attribute interferences to the chemical combinations which one base may make with the material of the membrane, thereby altering its permeability to another kation. Thus, True rests all variations in permeability of root-hairs upon the replacement of one base by another in the pectates of the wall and membranes. It is not at all clear that such replacements actually occur or that the compounds implied are present. The pectins are very weak acids, and it is not known definitely that calcium, potassium, and magnesium pectates are formed when these bases in the form of salts are infiltrated.

It may be plainly demonstrated that these bases cause the material of the wall to assume different degrees of permeability, varying density, etc. That these changes rest upon chemical reactions between pentosans and salts alone does not seem probable in view of the established presence of lipins in the walls and membranes. Furthermore, the change from a calcium pectate to a sodium or potassium pectate would not explain the wide range of variation or abruptness of changes in permeability. More adequate explanations may be based upon the colloidal condition of the material, which is in the form of a heterogeneous system of emulsoids.

The density or viscosity of such colloids is of course determined by the proportion of water present at any given temperature. The difference between the rates of diffusion of such substances as the ions of sodium, potassium, and magnesium in gelatine or agar with a small proportion and with a high proportion of water is so small as to be of but little importance in permeabilities of the kind discussed by the physiologist.

When salts are added to the water in which agar or gelatine may be hydrated the combined action of the kations and anions determines the degree of hydration. Thus, it has been shown that the hydration reached by agar, by biocolloids in solutions of potassium, sodium, and calcium, are widely different and the colloid would in each take on a certain pertinent viscosity.

These hydration values may be safely taken to rest upon the adsorption of the different kations by the molecular aggregates of the colloid, and such aggregates then have the specific capacity indicated by the final hydration value. The formation of these adsorption compounds may be tentatively offered as an alternative to the theory of True, that definite salts are formed between the substances in the colloids and the bases. Furthermore, when the colloid has adsorbed any base, it is found that its presence will retard the diffusion of another kation which might give the colloid a higher hydration capacity. This is in fact the essential feature in the interferences which have become known as "antagonisms" to the physiologist.

So important is the direct action of the kation on the colloid that when solutions of potassium, sodium, and calcium are placed inside an artificial cell with colloidal walls the ensuing endosmose or amount of water pulled through the wall is widely disproportionate to the calculated osmotic activity of the kations. A calcium solution with an osmotic value of 40 as compared with that of potassium at 28 shows an endosmose of 12 as compared with that of potassium at 60. A similar relation is shown when potassium calcium is placed in the immersion fluid of cells with contents, such as sugar, with superior osmotic concentration. The cell in potassium takes in more water than the one in calcium. The potassium would therefore appear to modify the membrane in such manner as to make it less permeable to sugar as well as to its own kations, while the calcium would have the reverse effect at the concentrations tested. This would also apply to living cell-masses of *Rubus*.

The external layer of the living and of the artificial cells in these cases appears to become a better osmotic membrane under the action of agencies which would increase hydration of the pentosanic component. That the increased hydration of an agar layer would not make it a more efficient membrane in osmosis is clear. It would appear, therefore, that the phenomena in question must be referred to the lipoid layer, and that when this layer is defective or slight, effects such as those shown by the walnut may be expected. The solutions of calcium used are known to cause a precipitation or aggregation of such lipins as lecithin, and this transformation would increase the permeability of the layer to kations, while the liquefaction of the layer would result from the action of potassium.

Much greater changes would result in both the living and the artificial cell than ones of simple hydration or coagulation. The action of any of these reagents which seriously alters the state of any one of the components of the heterogeneous system might be expected to cause partial or complete reversals of phase in the colloidal material, and such changes as suggested by Clowes might well be of such importance as to cause wide or abrupt changes in permeability. This author lays great stress on the action of soap films in heterogeneous systems. It is not clear that the existence of such films in plant cells could be safely predicated in view of their relatively high acidities in which they could not exist. Great variations in acidity may take place without corresponding alterations in permeability. At the same time it is to be noted that the presence of such fatty substances as the lipins in a two-phase condition, enmeshed with pentosans and possibly proteins, would make a heterogeneous system in which reversals of phase would entail wide variations in permeability.

The external layers of the cell, which are exemplified by the artificial cell used in these experiments, may be considered as a heterogeneous colloidal system in which the pentosans and lipins are the most important constituents. The kations of the ordinary bases of importance to the plant modify the hydration of the pentosans at the concentrations ordinarily encountered. These substances are seen to cause still more marked changes in the hydration of lipins, the reactions including flocculation or precipitation. Changes of this character would include reversals of phase and abrupt modifications of conductivity.

Interferences or "antagonisms," particularly between those which exert a strong effect on colloidal state and those which are less active, have been ascribed to simple modifications of hydration, but it is highly probable that flocculations and reversal of phases are concerned.

Effect of Salt Solutions on Hydration and Swelling of Plant Tissues,
by F. T. McLean.

The swelling of plant tissues when in contact with solutions is a resultant of a number of processes—osmotic pressure, hydration of the protoplasm and cell-wall, chemical changes in the plant constituents, etc. By using solutions which cause definite reactions with colloids similar to those in plant tissues or with certain groups of constituents of plants, it is possible to obtain indications of the importance of these substances to the maintenance of turgidity in plants and consequently to growth. With this end in view, young tissues of cactus (*Opuntia discata*) joints and of walnut (*Juglans major*) and blackberry (*Rubus vitifolius*) stem-tips were immersed in solutions of saponin, alanine, sucrose, d-glucose, and certain mineral salts, and their swelling recorded by means of the auxograph.

The concentrations of saponin tested (0.04 to 5.0 per cent) all caused rapid swelling of *Opuntia* tissues. This was followed by pronounced shrinkage to less than the original thickness. No shrinkage occurred in control sections swelled in distilled water. In 1 per cent and in 5 per cent saponin Merck, swelling was less than in water. Similar concentrations of saponin caused the same kind and amount of swelling of blackberry sections as did water, without subsequent shrinkage. Since saponin is a solvent for lecithin, the effects on *Opuntia* may be due to the solution or displacement of a lecithin layer in the plasma, thus rendering the cells more permeable to certain constituents and permitting exosmose and shrinkage. If this be the case, then the blackberry tissues either did not possess a lecithin layer or the permeability of the plasma to the principal osmotically active constituents was not affected by the removal of such a layer.

Low concentrations (0.03 M or less) of alanine, sucrose, and glucose had no marked effect upon the swelling of *Opuntia* or blackberry tissues. Sucrose caused shrinkage (plasmolysis) of *Opuntia* tissues at a concentration of less that 0.2 M, glucose at between 0.2 M and 0.3 M, KCl at 0.15 M, and KNO_3 at 0.15 M or slightly less. *Opuntia* tissue swelled in 0.2 M glucose, which is approximately isosmotic with the other solutions used, and it may therefore be concluded that glucose is more readily absorbed than sucrose, potassium chloride, or potassium nitrate.

A comparison of the swelling of walnut tissues in chlorides of potassium, sodium, magnesium, and calcium at 0.01 M concentration resulted in least swelling of the tissues in potassium, as compared to distilled water, and greatest in calcium. Another comparison of sulphate, chloride, and nitrate of potassium at 0.01 M gave the least swelling, both of blackberry and of walnut in sulphate (0.3 and 0.5 respectively of the swelling in water), and most in nitrate (1.1 to 2.1 compared to water). These effects of the kations and anions suggest that the aggregation of the plasma by nitrates and calcium salts, respectively, increase its efficiency as a semipermeable membrane, and thus permit great swelling due to osmotic pressure of the cell solutes.

Tests of the longitudinal swelling of young blackberry-stem tissues gave a quite different result for the chlorides of potassium, sodium, and calcium.

Five successive series of tests were made of different samples of these tissues, and the results are averaged in table 1.

Table 1.—*Relative swelling of stem-tips of blackberry in salt solutions compared to that in water as unity.*

Salt solution used.	Initial swelling or shrinkage.	Subsequent change.
KCl 0.005M	+0.7	none
KCl .010M	+1.7	none
KCl .01 M + $CaCl_2$ 0.0002	+1.3	none
NaCl .005M	− .3	+0.5
NaCl .005M + $CaCl_2$ .0001	+1.5	none
NaCl .01 M	−1.0	+0.4
NaCl .01 M + $CaCl_2$ .0002	− .5	+ .4
$CaCl_2$ .0002M	− .6	+ .5
$CaCl_2$ .005M	− .5	+ .5
$CaCl_2$ .01M	+1.1	none

The relative effects of potassium, sodium, and calcium chlorides is the reverse of that with walnut. Potassium permits the greatest swelling of blackberry, nearly twice as much as in water. The results with sodium and calcium were peculiar in these tests. The tissues consistently shrank when first immersed in the sodium-chloride solutions and in calcium chloride of less than 0.01 M concentration. The shrinkage was very prompt and continued only about 15 minutes, then, swelling quickly, brought the tissues to more than the initial thickness. Calcium chloride added to the sodium solutions in the proportion of 1 of calcium to 50 of sodium inhibited the shrinkage in sodium at 0.005 M and reduced the shrinkage to half in the 0.01 M concentration. In two tests after this series, however, no shrinkage was observed in NaCl 0.01 M.

Addition of HCl to NaCl solutions decreased the amount of swelling compared to that in the pure salt, and also shrinkage of the tissues took place after the swelling. Addition of KOH did not produce such effects.

Physical and Chemical Factors in the Growth of Asparagus, by Earl B. Working.

Asparagus was chosen as a suitable material for a study of certain aspects of the physico-chemical basis of growth.

Periodic measurements and continuous auxographic records were made of plants grown from storage roots and from seeds. Temperature, light, and soil conditions were varied in the different experiments.

The hydration capacities of shoots and of seedlings in a large variety of solutions were determined by means of the auxograph. Various chemical analyses and pH determinations were made.

Two series of sand cultures were grown to get further information concerning the effect of various salts, particularly those of Na, Ca, and Mg.

Commercial practices and conditions were studied, and these observations compared with the experimental results.

The following conclusions are thought to be supported by this work:

1. Shoots comparable in composition may be obtained at different times of the year if similar roots are taken from cold storage and forced for equal lengths of time.

2. Light has little or no immediate effect on the growth-rate of young shoots or seedlings, or on the height they attain before branching. Its effect is chiefly through the food stored from previous photosynthesis.

3. Light is an important factor in the production of new roots. It is suggested that this may be a result of the change in carbohydrate gradient due to photosynthesis.

4. The three external factors of greatest importance in the growth-rate of the young shoot are the temperature, the salt balance of the soil, and the moisture-content of the soil.

5. Temperature can not be considered a limiting factor in the narrowest sense of the term, as an improvement in the salt balance of the soil induces more rapid growth at the same temperatures.

6. Increase in growth-rate is always found with increasing temperature up to the highest which occurred in the experiments.

7. The height attained by the stalk before branching is governed chiefly by the temperature. If exhaustion of reserve food has an appreciable effect, it is observed first in the production of stalks of smaller diameter, thus preventing satisfactory comparison.

8. The addition of sodium salts in low or medium concentration (0.001 to 0.2 molar) improves the salt balance of the soils and culture solutions used.

9. With the culture solutions used magnesium salts begin to show an injurious effect at a concentration of about 0.02 molar.

10. The amino-acids present in the young stalk are favorable to high imbibitional swelling of a protoplasm containing a large percentage of pentosan.

11. Temperatures favorable for commercial growth are limited on the one side by reduced growth-rate and on the other by the early branching induced. The color, texture, and slope of the soil are important in regulating soil-temperature, which is of special importance when white asparagus is grown.

PHYTOGEOGRAPHY AND ECOLOGY.

Indirect Factors influencing the Vertical Distribution of Vegetation,

by Forrest Shreve.

Data on the vertical distribution of vegetation secured during several years of field work in different parts of southern Arizona have been collated and prepared for publication. The nature of the physical conditions which determine the vertical distribution of vegetation on desert mountains is now well known. Throughout the mountains of southern Arizona there is a close degree of correspondence between the sequence of the several types of vegetation encountered in ascending from 2,000 to 10,000 feet. The comparison of distributional data from several mountains reveals some striking differences in the absolute altitudes at which familiar transitions take place. The precise altitudinal limits of the main types of vegetation are strongly influenced by the departure from the normal altitudinal gradients of physical conditions that are initiated by certain large topographic features. The principal of these is the altitude of the plain from which a given mountain rises. In the region under consideration the lower limit of encinal and forest is determined by the elevation above the basal plain more nearly than it is by absolute elevation. Also, the total elevation attained by a mountain determines the vertical limits of its types of vegetation. The upper slopes of a small mountain will be covered with a vegetation which reaches its upper limit from 1,000 to 2,000 feet lower on a large mountain.

These features are related to differences in rainfall, movement of convectional storms, cold-air drainage, and other factors as to the operation of which considerable is known from earlier work in this region. With them are associated differences in the altitudinal limits of vegetations and species due to differences in soil character. If a mountain is taken as the norm which has a loam soil of granitic origin, it will be found that the lower limits of encinal and forest are higher on rhyolitic and other volcanic soils (except basaltic clay), and are still higher on limestone soils.

Measurements of Erosion and Deposition as related to Vegetation, by Forrest Shreve.

Biennial measurements have been made for two years on four series of metal bench-marks established permanently in the Avra Valley and on the bajada of the Sierrita Mountains near Tucson. There are two series of bench-marks in each locality, one running parallel to the drainage in small streamways, the other transversely to the lines of drainage. The streamway in the Avra Valley has a very low gradient and is surrounded by a region of indeterminate drainage. The streamway on the bajada of the Sierrita Mountains has a fall of about 100 feet to the mile, and the region which it drains is gently rolling in transverse section.

In both of the series of bench-marks placed in the streamways there has been an irregular alternation of erosion and deposition, such as is common to all streamways, of whatever size, that are fed only by torrential desert rains. The nodes at which there was no change of elevation are from 50 to 100 meters apart. The bench-marks placed transversely to the present drainage in the Avra Valley have shown little change other than a slight deposition near the largest streamway and a slight erosion at one spot where a new streamway is developing. On the bajada of the Sierrita Mountains the transverse series has shown a consistent cutting down of the elevated spots and a filling of more than half of the very small drainageways comprised.

Great irregularity in erosion and deposition is to be expected from year to year in all of these series, and it will require a number of years to determine the trend of events at the places under investigation. The vegetation of the Avra Valley bears abundant evidence of the abrupt changes of physical conditions that have accompanied heavy deposition of very fine material or the rapid development or filling of drainageways. It is hoped that some evidence can be secured through the bench-marks as to the magnitude and chronology of these changes.

Stem Analysis of Monterey Pine and Redwood, by Forrest Shreve.

Further study has been made of the longitudinally bisected pine (*Pinus radiata*) cut in 1921, and a redwood (*Sequoia sempervirens*) of similar size has been prepared for examination in the same manner. The combination of longitudinal and transverse sections has made it possible to secure a set of precise measurements with which to compare the rate of growth of these trees at different heights from the ground, as well as to investigate the correlation between growth and rainfall.

An examination has been made of the relative growth performances of different portions of the trunk in the pine. The greatest diameter increment in a single year was 3.3 cm., which took place at a height of 5 meters at a time when the pine was 7 meters high and 8 years old. This rate was equaled and approached at about the same age and horizon in other cases. During the first 16 years of the life of this 38-year-old tree the maximum growth for each year took place from 2 to 5 meters below the top. After the attainment of a height of 17 meters, which is near the total of 20 meters, the region of maximum growth in diameter fell to a zone from 5 to 9 meters below the top. In comparing the 19 cross-sections of the trunk, taken at 1-meter intervals, the maximum growth at each of these horizons is almost invariably found at the center or within 4 years of it. In comparing the growth in thickness for a single year at all of the 19 horizons, a very pronounced irregularity is found. This was greatest after the tree had reached a height of 15 meters and an age of 17 years. Correlations between growth and any environmental condition would differ widely if based on growth as measured in a stump section or measured at some other horizon.

For the purpose of correlating growth and rainfall two sets of growth data were used: (1) the increments shown by the stump-section, and (2) the average increments of the 10 lowest transverse sections. The former is the commonly used datum, the latter should give a much more accurate measure of the total growth performance of a tree. A comparison of graphs of annual growth as determined by the two methods shows that in 22 out of 32 years there was the same behavior on the part of the stump and the trunk as a whole.

The redwood exhibits a march of growth which is much more orderly than that of the pine. The increments of any two years, when followed up the tree, sustain the same general relation to each other. There is a complete agreement between graphs showing growth at the stump and for the 10 trunk-sections. The maximum diameter increase in a single year was 2.3 cm. As in the pine, the maximum growth in each year was within a zone 2 to 3 meters from the top, and at each horizon was found from 2 to 4 years from the center of the section.

With a view to determining the degree to which rainfall may be responsible for the fluctuations in growth-rate from year to year, several sets of qualitative correlations were made for the pine and the redwood. Growth data have been used from stump alone and from the average of 10 trunk-sections in each tree. Correlations have been made with the total annual rainfall and with four sets of seasonal rainfall data covering different groups of months. The results indicate: a closer correlation of growth with rainfall in the redwood than in the pine; a much closer correlation in the pine from 20 to 40 years of age than from 1 to 20 years; a closer correlation for both trees with the rainfall of the months from December of the preceding year to September than for any of the groups of months more closely coinciding with the growing season; a closer correlation of the rainfall of nearly all month groups with the stump data than with the average data from the 10 sections.

These results indicate a positive correlation between the growth of pine and redwood and seasonal rainfall. Also that the growth in thickness of the basal portion of the trunk is influenced more by rainfall than is the growth of the trunk as a whole, and that the total annual growth performance of these trees, in the California coastal climate, is dependent on the precipitation of the two or three months which precede the initial spring growth.

Relation of Altitude and Slope Exposure to the Temperature of the Soil, by Forrest Shreve.

During the summer of 1922 a series of six soil thermographs was maintained on the Santa Catalina Mountains, near Tucson. The instruments were in pairs at 7,000, 8,000, and 9,000 feet, one of each pair being installed on a north-facing slope and the other on a south-facing slope. The gradient of the slope in each case was close to 15° from the horizontal. At 7,000 feet the soil was loam of granitic origin, very poor in organic matter, at the other elevations a clay loam overlying diorite and rich in humus. The bulbs of the thermographs were placed at a depth of 3 inches in situations with natural vegetation, typical of the several elevations. The surface above the bulbs was covered with a litter of pine or oak leaves at the two upper stations and was relatively bare at the 7,000-foot station. The shading of the soil varied at the different stations, in keeping with the difference in the character of the vegetation, from an almost continuous shade at the station on the north-facing slope at 9,000 feet to almost complete insolation on the south slope at 7,000 feet. This circumstance is calculated to augment the differences to be expected at such stations, but the results indicate the conditions actually encountered by the vegetation much more nearly than would be the case if each instrument was installed so as to secure continuous insolation.

In a similar series of observations taken in 1921 at 3,000, 4,000, and 5,000 feet (see Annual Report, 1921) it was found that during April and May the maximum soil-temperature increased with altitude, and that the maximum readings for north slopes were slightly in excess of those for south slopes. As the general validity of these results at other elevations and other seasons seemed highly questionable, the 1922 observations were planned to cover a longer period at elevations exhibiting a more pronounced differentiation of vegetation and on slopes of slightly greater gradient than those employed in 1921. The data for the first 14 weeks have been analyzed on the basis of the calibrations of the instruments at the time of installation. The first seven weeks were dry, the second seven intermittently rainy. For the stations at 8,000 and 9,000 feet there is a consistently higher soil-temperature on the south slopes than on the north slopes, the average difference at the former elevation being 15.2° for the dry weeks and 11.0° for the wet ones, and at the latter elevation 13.6° for the dry weeks and 11.7° for the wet ones. For the station at 7,000 feet the average temperature, derived from the daily maxima and minima, was higher on the south slope by 8.9° in the dry weeks and 8.3° in the wet ones. There were also four weeks on which the average weekly maximum for the north slope approached that for the south slope within 3° to 5°, these being the hottest weeks of the entire period. These results approach the character of those secured at the lower elevations in 1921.

The influence of slope exposure on the vertical distribution of vegetation has been found to be such that there is a general correspondence between the vegetation of a north slope and a south slope 1,000 feet higher. It has been shown that the ratio of evaporation to soil moisture corresponds on opposed slopes 1,000 vertical feet apart, but a similar comparison of soil-temperatures shows that a south slope has a consistently higher temperature than a north slope 1,000 feet below it.

The influence of altitude on the temperature of the soil is found to be slightly greater on south slopes than on north slopes. For all of the four comparisons made possible by the data secured in 1922 there is a fall of 6.3° to 6.8° for each rise of 1,000 feet on slopes of the same exposure. The average temperature of the soil at 3 inches on the south slope at 9,000 feet is approximately 20° lower than the soil temperature at the same depth on level ground at the Desert Laboratory, 6,500 feet below.

Atmometery in South Africa, by W. A. Cannon.

In connection with studies carried out in 1921 on vegetation and environment in certain portions of South Africa, a comparative investigation of the evaporation power of the air in several unlike stations was initiated and carried out with the assistance of the Botanical Survey of South Africa and various scientists not connected with the Survey. Cylindrical atmometers were employed. In the preliminary studies atmometers were placed and read at the following stations: Messina, Low Veld; Pretoria, High Veld; Pietermaritzburg, Eastern Grass Veld; Grahamstown, Cape Town; Swakopmund, Southwest Africa; and Beaufort West, Whitehill, and Matjesfontein, Great Karroo. Introductory reports from several of the stations are now available and a summary of some of the results can be presented. The period under consideration is from July to December, inclusive, although no one station has records covering the entire time. The seasons, therefore, are those of winter, spring, and early summer.

A comparison of atmometer readings from the Karroo as contrasted with those of certain other regions will be of interest. At Beaufort West, eastern Karroo, where the average annual rainfall is 9.51 inches, of which over 60 per cent occurs in the warm seasons, the atmometer records of August to December show weekly evaporation extremes of from 181 to 615 c. c. These were obtained two successive weeks in September. The total evaporation for September and October was 3,089 c. c. At Matjesfontein, western Karroo, with an annual rainfall of 6.96 inches, of which over 60 per cent occurs during the cool seasons, the total evaporation for September and October was 2,554 c. c. The least weekly evaporation for the two months was 170 c. c. and the greatest was 437 c. c. The former occurred the first part of September and the latter late in October. At Grahamstown, between the Great Karroo and the south coast, with an annual precipitation of 28.79 inches, of which over 60 per cent occurs in the warm seasons, the total evaporation for September and October was 1,577 c. c. The weekly extremes were 119 and 260 c. c. The total evaporation at Pietermaritzburg during the same months was more than at Grahamstown but less than at either of the Karroo stations named. The annual precipitation at Pietermaritzburg is 35.97 inches, of which over 80 per cent is in the warm seasons.

A comparison of the average precipitation for September-October at these stations with the observed evaporation for the same months in 1921,

$$\frac{\text{precipitation } p}{\text{evaporation } e},$$

gives a measure of their relative aridity which is of value. Thus, at Beaufort West the average September rainfall is 0.52 and that for October is 0.99 inch. The total evaporation for each of these months, 1921, was found to be 1,414 and 1,675 c. c. respectively. The precipitation-evaporation ratios (p/e) for Beaufort West are 0.000367 September and 0.00021 October. The average rainfall at Matjesfontein for September is 0.29 inch and for October 0.36 inch. The total evaporation for the two months, 1921, was found to be 902 and 1,650 c. c., respectively. The p/e ratios, therefore, for September and October at Matjesfontein are 0.00032 and 0.00021. At Grahamstown the average precipitation for September and October is 3.28 and 3.1 inches. The evaporation for the two months, 1921, was 754 and 823 c. c. The p/e ratios for the two months are, therefore, 0.0042 and 0.0037. The relative aridity of the Great Karroo in spring is further indicated by a comparison of the p/e of Beaufort West, Pietermaritzburg, and Kirstenbosch for November. Of these stations the annual rainfall at Kirstenbosch (Bishop's Court, Cape Town), is about 52 inches, of which about 80 per cent occurs in the cool seasons. The average precipitation for November at each of the stations is as follows: Beaufort West, 0.75 inch; Pietermaritzburg 5.7 inches; and Kirstenbosch (Bishop's Court), about 2 inches. The total evaporation in November 1921 was found to be 1,216 c. c. at Beaufort West, 955 c. c. at Pietermaritzburg, and 927 c. c. at Kirstenbosch (National Botanic Garden). The November p/e ratios, therefore, are as follows: at Beaufort West, 0.00061; at Pietermaritzburg, 0.00576; and at Kirstenbosch, 0.0021. These ratios indicate the march of the seasons with the accompanying characteristic changes in aridity, not only in the well-watered regions, but also in those not thus so well favored. And they reveal in a striking manner the relative great aridity of portions of the Great Karroo.

The obtained results point also to the possible importance, as influencing the evaporation-rate and hence as having noteworthy effect on plant life, of such factors as prevailing winds, as the influence of neighboring highlands or regions of greater or less moisture, and as the effect of ocean fog. The relation of certain such secondary environmental factors can be briefly referred to here. They are of especial importance in regions of little precipitation. Thus, in the Great Karroo the kind as well as the abundance of the vegetation is often associated with aspect. This feature is well exemplified by the vegetation of isolated small hills, or kopjes, which may be unlike on the north and on the south sides. Atmometer readings on the sides of the kopjes toward more arid or warmer regions, or on the warmer side of the kopjes, are noticeably higher than on the opposite aspects, and these results appear to be in good correspondence with the relative xerophylly of the vegetation of the two sides. Again, the relatively abundant vegetation in portions of the Great Karroo where the rainfall is small is probably to be associated with a fairly high humidity of the air due to winds from contiguous regions of higher precipitation. Analogous conditions obtain with 50 kilometers, more or less, of the coast in the Namib. This is shown at and near Swakopmund. With an average precipitation of 0.65 inch, the rate of evaporation at Swakopmund in winter and spring is surprisingly low. This is affected in a marked manner by the direction of the winds and by fog. Thus for four days ending July 13 a water-loss of 342 c. c. was recorded. For a portion of this time a land wind from across the arid hinterland (Namib) was blowing. At another time the atmometer lost only 132 c. c. in eleven days during a period of fog. And, finally, the total water-loss of September and October was only 1,581 c. c., which, it will be seen, was about the same as at Grahamstown with a precipitation amounting to 28.79 inches. Sparse as it is, the vegetation of the western Namib would not be so abundant if it were not for the marked and direct effect on evaporation of the fog.

On the Transpiring Power of some Karroo Plants in Winter and Spring,

by W. A. Cannon.

The rapidity with which desiccated strips of paper impregnated with cobalt chloride change color when placed on the surface of leaves as compared to the rate of change over a free water-surface, the index of transpiring power of Livingston,[1] was observed in several native and introduced plants in certain of the more arid parts of South Africa, especially in the Great Karroo, in late winter and in spring of 1921. The growth-habit of the species examined included herbaceous forms, annuals and perennials, as well as shrubs and trees. The ascertained indices of transpiring power

$$\frac{\text{Rate of color change over water}}{\text{Rate of color change on leaf}}\ e/t$$

for the species examined showed a considerable range of variation as between species, and in the same species, but nevertheless is relatively low, as appears in table 2.

TABLE 2.—*Maxima and minima indices of transpiring power of Karroo plants, July to October 1921.*

	Maximum *e/t*.	Minimum *e/t*.
Aloe schlechteri	0.257	0.019
A. striata	.06	.0085
Cotyledon coruscans	.016	.0033
C. paniculata	.04	.0048
Euyrops laterifolius*	.204	.015
Gasteria disticha	.097	.009
Grewia cana*	.307	.022
Gymnosporia buxifolia*	.52	.04
Massonia latifolia	.171	.052
Protea neriifolia*	.41	.14
Rhus lancea*	.148	.053
Rhus sp.*	.297	.157

*Average of maximum and of minimum of both leaf-surfaces.

Although the studies were carried on during only a portion of the year, they suggest several features of ecological import, some of which can be referred to in this place. Of the species given above, the *Aloes*, *Cotyledons*,

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[1] B. E. Livingston, The resistance offered by leaves to transpiration water-loss, Plant World, vol. 16, p. 1 (1913).

Gasteria, and *Massonia* have a notable water-balance. The water-storage capacity of *Aloe, Cotyledon coruscans*, and *Gasteria* is in the leaves, while that of *Cotyledon paniculata* is in the very much enlarged and stout stem, and that of *Massonia* in the underground enlarged portions. *Gasteria* and *Massonia* are perennial herbaceous forms. Although all of these forms have relatively low transpiring indices, as indicated by the table, the indices probably vary with the seasons, as well as with a variation of different environmental physical factors, and with the physiological condition of the individual. Thus, the relatively high transpiring index of *Aloe schlechteri* was obtained at the time of flowering, in late winter, and when evaporation rates, as told by readings of the atmometer, were relatively low. That of *A. striata*, on the other hand, was in midspring, when the species was past flowering and when the high evaporation rate of spring and summer was already close at hand, as foreshadowed also by the atmometer. Studies on *Cotyledon*, on the other hand, were conducted in midspring, and both species were growing under parallel environmental conditions. In both species it appears possible that the maximal indices given may indeed represent the highest for the entire year. The slight difference in the magnitude of the index as between the species with succulent perennial leaves, *C. coruscans*, and the species with deciduous leaves and succulent stem, is probably significant. In the latter, *C. paniculata*, leaf fall was proceeding four weeks after the tests on it were made. This species is confined to regions where the water-relations are relatively good. But a similar result as between species with water-balance in the leaves and in the stem was obtained in *Gasteria* and *Massonia*, and it may be characteristic of such morphological differences.

The sclerophyllous species have all a fairly high index of transpiring power, although they vary considerably among themselves in this regard. Thus, *Protea neriifolia*, which occurs where the rainfall is relatively high, was observed to have, in late October, a relatively high index. Other species which were studied during the same time, such as *Euclea, Euyrops*, and *Rhus*, were found to have much lower indices than that of *Protea*, but at the same time much higher than that of the species with water-balance. *Rhus lancea* occurs along streamways at Matjesfontein, rainfall 6.96 inches, and *Euyrops laterifolius* under relatively favorable moisture conditions in the same vicinity. It is to be noted that the minima indices of these species approximate the maxima of those previously referred to. Shrubs with perennial leaves may show equal or very unequal transpiring power of the two leaf-surfaces. In *Gymnosporia* the former condition appears to obtain, and in others, notably in *Euyrops, Rhus*, and *Protea*, the latter. In the case of *Euyrops* and *Rhus*, the ventral surface has the larger index, but in *Protea* the maximum index was obtained on the dorsal surface. In *Protea*, as the leaf matures it assumes a permanent erect position with the ventral surface facing outward and hence especially exposed to the wind, to light, etc. The difference in index of transpiration between the dorsal and ventral leaf-surfaces in *Protea* is less marked in young leaves. The transpiring power also increases toward the leaf-tips. The greatest difference between the two leaf-surfaces in transpiring power was found in *Gymnosporia*, in which the ratio was about 20 to 1, denoting little water-loss from the dorsal surface. The differences in transpiring power of leaves on one and the same specimen, as well as differences between perennials of unlike habit but occurring under similar conditions, were observed at Matjesfontein in *Eucalyptus globulus* and in *Cotyledon paniculata,* both of which had been introduced, subsequently abandoned, and not irrigated. On October 4, the index of transpiring power of *Cotyledon,* between $7^h\ 50^m$ a. m. and $5^h\ 50^m$ p. m. ran from 0.013 in early morning to 0.0089 at $2^h\ 08^m$ p. m., rising afterward to 0.02 near evening. In the case of the *Eucalyptus,* circular but mature leaves of the juvenile type and elongated leaves of the adult type were studied. In the former the index varied from 0.32 in the morning to 0.1 in midafternoon and 0.36 in early evening. In the adult type of leaf, however, the index varied from 0.08 to 0.1 during the course of the day. The maximum index of the elongated form of leaf thus was the minimum of the juvenile type. But the minimum index of the adult leaf was very much greater than the maximum index for *Cotyledon* growing in this instance under apparently similar environmental conditions.

A single series of studies on the transpiring power of *Welwitschia mirabilis* was carried out early in July and merits especial notice because of the great interest of the species. The habitat where the tests were made is on the Namib plain immediately south of the Swakop River and about 50 kilometers east of Swakopmund. It lies on the eastern edge of the coastal fog-belt, where, because of the fog, as shown in another place in this report, the rate of evaporation is frequently low. There are few specimens of *Welwitschia* at the place which are scattered over an area 1 kilometer or more in diameter. The specimens especially studied were about 2 meters from tip to tip of the diverging leaves which lie freely on the surface of the ground. The ends are frayed by the wind, but the basal half, more or less, is intact. At the tips the leaves are brownish, but for the most part they are green, which assumes a bright grass-like hue at the base. The leaves are apparently devoid of pubescence, but a double epidermis[1] and deeply sunken stomata prevent rapid loss of water from the surface. The tests of the transpiring power were confined to the dorsal, upper surface, immediately above the base of the leaf. The study was begun about 3 hours after sunrise and was continued about an hour. Several readings were made. The average length of time required to complete the color change from dark blue to light blue was found to be 120 seconds, which gave 0.0138 as the index of transpiring power. When this index is compared with those of other species from arid regions, as from the Karroo, which were obtained at the same season of the year, it is seen that that of *Welwitschia* is relatively and actually very low, which ranks the species among the most marked of xerophytes.

Seasonal Changes in Water Relations of Desert Plants, by Edith B. Shreve.

With a desire to discover the responses by which desert plants meet the conditions that approach the critical point of the physiological limits of their endurance, the daily march of the processes that are dependent upon water-condition has been investigated for selected typical desert plants and, for the sake of comparison, the same experiments have been performed upon a cultivated plant which will thrive during certain seasons. The plants used were *Encelia farinosa* (a perennial), *Streptanthus arizonicus* (a spring annual), *Amaranthus palmeri* (a summer annual), and *Phaseolus* sp. (Papago bean).

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[1] M. G. Sykes, The anatomy and morphology of the leaves and inflorescences of *Welwitschia mirabilis,* Phil. Trans. Roy. Soc. of London, ser. B, vol. 201, p. 180.

A partial report upon the results of this work has previously been made.[1] Since then further experimentation has been carried on with these plants under controlled conditions. Simultaneous measurements have been made of the daily march of transpiration, of water-content of plant parts, of stomatal apertures, of leaf temperatures, of the evaporating power of the air, and of soil water-content. The entire series of experiments has extended over several years and the results have now been brought together and presented for publication. Following are the outstanding conclusions:

During the season when abundant moisture is accompanied by relatively low temperatures, the spring annual is living under conditions which are very near the limit of its endurance to aridity. It could not live during the summer rainy season, when favorable soil-moisture conditions are accompanied by high temperatures and a greater evaporative power of the air, even if it could be made to germinate under artificial conditions. The summer annual is able to live through temporary drought periods of several weeks' duration by lowering its response to the evaporative power of the air and by remaining in a wilted condition from which it easily recovers. It seems probable that it could flourish in the spring rainy season, except for the fact that it will not germinate at the lower temperatures which exist at that time.

Phaseolus grew well under conditions of high humidity and relatively low temperatures, but died when exposed to air of low humidity and high temperature, even when the soil water-content was kept high. The perennial approaches its limit of endurance only in the arid fore-summer. It is able to live through this unfavorable period by lowering its response to the evaporative power of the air and by decreasing its total leaf-surface. It has a somewhat mesophytic type of leaf during the favorable late winter and spring months and a much smaller, more xerophytic form during the drought season. Furthermore, in the arid season the stems and leaves contain in abundance a dark-colored, gummy semi-fluid, which is either entirely or almost absent in the more humid season. The theory is advanced that this substance is at least partially responsible for the greater resistance to water-loss in the arid season.

It appeared clearly that the best measure of the response of a plant to any given aridity is indicated by the ratio T_c/E_m, the denominator of which is the maximum rate of evaporation from an atmometer for the day under consideration and the numerator the corresponding rate of transpiration per unit area. In all but a very few cases the maximum transpiration for the day occurred earlier than the maximum evaporation. The more favorable the humidity conditions the closer the two maxima approached in time. Humidity indices were obtained by dividing the evaporation-rate for 24 hours by the soil-moisture per unit dry weight (E/S); and the T_c/E_m ratios for the various plants in their several seasons were compared with the corresponding humidity indices. For the three native species the T_c/E_m ratio increases directly with the humidity index. The beans stand out in strong contrast to the successful species in showing the ratio to have the same value for the humid season in which they flourished and in the dry hot season which caused their death.

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[1] Carnegie Inst. Wash. Year Book for 1919, p. 101.

The three native species showed an ability to increase their resistance to water-loss with increasing aridity, and thus appeared to obey Le Chatelier's theorem, which states "Each change in an outer condition that affects a body or system produces in it a change in such a direction that as a result of this change the resistance of the body or system to this outer change is increased." The cultivated plant did not show this phenomenon, but the system was destroyed, since the plant died under the more arid conditions. Thus, here appears the beginning of the application to biology of a law which has already been found to be universally true both in physics and chemistry.

The results of investigations of stomatal movements and the lowering of leaf-temperature by evaporation show that, while all of these phenomena aid in bringing about resistance to increasing aridity, they are not sufficient to account for the marked increase in resistance to water-loss shown with increasing evaporating power of the air.

For each species of the plants, a number approaching a constant was obtained when the ratio $T/E \times S$ was calculated, T representing the transpiration per unit area for a 24-hour period, E the loss from an atmometer for the corresponding period, and S the water-content of the soil per 100 grams of dry weight. Thus it appears that transpiration varies with both the evaporating power of the air and the soil water-content.

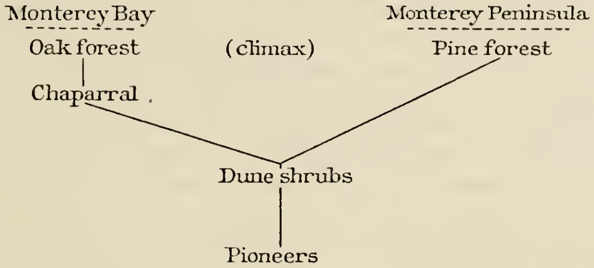
A comparison of the daily and of the seasonal water-content of plant parts with the transpiring power of the plants shows that the amount of water in the plant undoubtedly influences the rate of transpiration. That is, when the water-content of the plant is lowered, the capillary and colloidal imbibitional forces become greater.

The appearance of a physical constant for the physiological behavior of a given species under different conditions and the very apparent obedience of a biological process to a general physical law are the most interesting results obtained from the work.

Strand Vegetation of the Pacific Coast, by William S. Cooper.

During the summer of 1922, field work in the Monterey region was practically completed. In a continuation of the study of the ancient dune area bordering Monterey Bay, east and northeast of Monterey, in which the detailed vegetation map begun in 1919 was finished, the limits of the dune region were determined and also the relations of the dunes to the underlying geological formations. Four permanent quadrats, established in 1919, were recharted. The most obvious changes noted were continued destruction of pioneer vegetation by both erosion and deposition in an active blowout area; notable increase of dune shrubs, especially *Lupinus chamissonis*, on the lee slope of a stagnant sand trail; increase of *Lupinus* and *Arctostaphylos pumila* on an ancient dune area burned over 7 years ago; and slackening growth-rate, as compared with previous years, of a large prostrate plant of *Arctostaphylos pumila* 5 meters in diameter. A portable apparatus for photographic recording of quadrats 1 meter square, making reproductions of such areas on a scale of one-tenth, was constructed and used for the first time in the above studies.

Particular attention was given to exploration of the dune areas of the Monterey Peninsula, and some important divergences in the successional processes from those occurring along Monterey Bay were discovered. The immediate cause of these differences lies in the presence in the former area of a different climax—the Monterey pine (*Pinus radiata*). The relations of the developmental processes in the two regions may be represented thus:



It is hoped that habitat data gathered during the past four summers will bring to light the more fundamental causes for these divergences.

Endemic Trees of the Monterey Peninsula, by William S. Cooper.

(1) *Monterey pine* (*Pinus radiata*).—The distribution of the species in the Monterey region was plotted upon a base-map as a first step in an attempt to explain its peculiarities of present range. Much new information was obtained with regard to its relations to soil and to other communities, special attention being given to the tension lines between pine and other vegetation types. Eroding sand dunes and excavations in the same afforded excellent opportunities for the study of its root system. A comparative rainfall study of the region has been carried on for three years. The results for the season 1919-20 have been reported. In 1920–21 several of the instruments met with disaster. The results for 1921–22 confirm the conclusions tentatively drawn after the season 1919–20: that the Santa Lucia mountain mass is the determining factor in producing local differences in the seasonal total, which were even more striking in the past winter than in 1919–20; and that the distribution of Monterey pine (and also Monterey cypress) bears no direct relation to these differences.

(2) *Monterey cypress* (*Cupressus macrocarpa*).—The distribution of the species was mapped as in the case of the pine, with special reference to the localities and conditions where reproduction is taking place. Along the southern coast of the Monterey Peninsula, where the cypresses grow in a thin line close to the shore, they were found to be invading the pine forest that dominates the peninsula in one limited area; elsewhere they are barely holding their own. Individual trees growing under a variety of conditions were carefully examined, and material was collected for comparative anatomical investigation. Through the courtesy of the Del Monte Properties Company a number of complete trunk-sections were obtained from stumps of some of the largest trees. These revealed striking abnormalities in manner of growth which await detailed study.

DEPARTMENT OF EMBRYOLOGY.

GEORGE L. STREETER, DIRECTOR.

One of the major projects in the program of work of this laboratory is the standardization of stages in the normal development of the human embryo. Our provisional plan is limited to the period beginning with the closure of the anterior neuropore and ending with specimens about 30 mm. long, representing the time from the beginning of the fourth week to the end of the ninth week of development, when the principal features of the external form of the body have become established. We have found that this period can be subdivided into 16 stages which are clearly marked off from one another. Of these stages careful studies of 7 have already been completed. Duplicate models of them, showing the details of the external form of the embryo, have been prepared and placed in a few collaborating embryological laboratories, in order that the proposed subdivisions may be tested out by other workers.

The adoption of stages of development has been found necessary, as it has become apparent that we must have other objective characteristics than mere size for the determination of age. The practice of basing such determination on the length of the specimen, which is the custom at present among anatomists, has proved unsatisfactory in several respects. A particular source of error lies in the fact that young embryos vary greatly in length, according to the posture in which they happen to undergo fixation. Furthermore, when placed in formalin or other fixing solution they become distended to a degree that adds considerably to their length and weight. This increase in volume varies with the size of the specimen and the condition of its tissues. Smaller specimens undergo a greater relative increase than the larger ones and fresh specimens greater than macerated ones. Moreover, this acquired distention gradually disappears and the size and weight of a given specimen will vary according to the time that has elapsed since its fixation. These sources of inaccuracy, which are disturbing in the case of young embryos, are of less importance in larger fetuses, because in these it is possible to standardize the measurements more accurately and to control fully the posture of the specimen. In the large fetuses, also, the increasing imperviousness of the integument retards the absorption of the fixative solution and the weekly increment in size reaches proportions that render the distention a factor of progressively diminishing importance. For the larger specimens a fairly satisfactory curve of growth, showing the correlation between weight, sitting height, head-size, foot-length, and menstrual age from the eighth week to term, has already been published from this laboratory and was referred to in the Year Book for 1920.

The period during which length is particularly unreliable as an indication of age, and for which we are in the greatest need of more accurate criteria of development, is the first two months. This was pointed out by Dr. Mall, who proposed the subdivision of this period into stages, based upon the development of external features, such as the branchial arches, arms, and legs. In attempting this standardization it soon became apparent that it would be necessary to survey more carefully than had previously been done the details of the external form. This is particularly true of the human

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embryo, in which the difficulty of distinguishing between real and accidental differences is increased by the varied conditions under which the material for study is obtained. This meant the study of more specimens and better photographic records, planned so as to display clearly the individual regions. Toward this end Professor Spaulding made in this laboratory, in 1921, a detailed study of the steps in the differentiation of the external genitalia. The successful outcome of his investigation testifies to the wisdom of temporarily limiting one's attention to a definite region. It is clear that before a satisfactory series of developmental stages, based on external form, can be decided upon, it will be necessary to study each part of the body and establish the normal sequence of differentiation, region by region.

During the past year I have studied the branchial region in the same way that Spaulding studied the external genitalia and have followed the transformation of the tissues in the neighborhood of the first gill-cleft into the definitive auricle. In addition to the detailed information obtained concerning the surface anatomy of the embryo, several features in the development of this region have been brought out through this study which are of importance because of their bearing upon the more general problems of development. I may mention particularly the evidence of the participation of the ectoderm in the differentiation of the underlying tissues. The study referred to shows that the auricular cartilage acquires its form with all the precision and individuality shown by other cartilaginous parts of the body. The examination of a great many specimens, covering the period from 30 mm. to full term, reveals the fact that there is a great variation in the detailed form of the auricle just as exists in the adult ear; that is, the individuality of the ear is expressed early, as soon as the respective parts can be identified. The part that varies least is that concerned in the attachment of the ear to the head, while the part varying most is the scapha-helix. An important consideration in the study of the auricle of the embryo is the functional bearing of its component parts. In view of this, I examined the auricles from a representative series of adult primates and compared them for the presence of uniform characteristics and the correlation of the latter to the special functional requirements of the various species. As in the embryo, the most uniform part is the apparatus for the attachment of the auricle to the head; the next in order is that portion concerned in the conduction of sound-waves into the meatus, together with its protective closure mechanism, and the least constant is the scapha-helix. The study of the striking differences in structure exhibited by the auricle in various animal forms reveals the fact that most of their auricular individualities are in the nature of remarkable morphological adaptations to their varying physical requirements.

CYTOLOGY.

Chemistry of the Living Cell.

Owing to the industry of the biological chemists, we are fairly familiar with the various chemical substances contained in the cells forming the elements of the body-tissues, but since most of the methods of analysis cause the death of the cell, they have been able to tell us very little of the chemistry of living cytoplasm. The progress made in this laboratory in the development of the methods of tissue-culture has rendered possible an approach toward such a field of inquiry. In previous reports mention was made of observations on the behavior of living cells toward certain differential stains, and an account has been given of the studies of Professor W. H. Lewis on the reactions of cells to the strong oxidizing reagent, potassium permanganate, which produces phenomena resembling certain features of mitosis. The importance of the presence of dextrose in the medium of tissue-cultures has been shown by Mrs. M. R. Lewis, whose completed paper has just appeared. In continuation of her work upon the chemical nature of cytoplasm, Mrs. Lewis has studied the cells of small pieces of fundulus embryos explanted into hanging drops of a suitable sea-water solution. By exposing the cells to iodine vapor she has been able to demonstrate the presence of a substance that yields the characteristic reactions of glycogen. When soluble starch was added to the medium, even after an exposure of a number of days, it did not appear to be utilized by the cells to store up glycogen. However, when dextrose was eliminated from the medium, the glycogen-resembling substance was decreased, although the presence of the latter could not in this way be entirely inhibited.

Reaction of Living Cells to Bacteria and Toxic Substances.

The behavior of living cells when brought in contact with bacteria is of considerable clinical interest. It will be remembered that Mrs. Lewis studied the peculiar effect of the typhoid bacillus upon cells, which appears to be characteristic for this organism. During the past year D. T. Smith, H. S. Willis, and M. R. Lewis have followed the behavior of cultures of chick-embryo tissue containing avian tubercle bacilli. They found that under these conditions the bacilli were taken in by clasmatocytes, fibroblasts, white blood-cells, endothelial cells, mesothelial cells, ectodermal cells, liver-cells, renal epithelium in the tubules, and cells lining the bronchiales and alveoli of the lungs. No microorganisms were observed in the red blood-cells, striated-muscle cells, nerve-cells, or ciliated epithelial cells. It is of importance to note that tubercle bacilli are taken into these cells precisely as are foreign bodies. Entrance into the cell is dependent upon the consistency of the cytoplasm, the composition of the foreign body, and also its position in relation to the surface of the cell. The only bacilli that are taken in by the cells are those which come in contact with the cytoplasm throughout their entire length. It is quite clear that the cell does not make any purposeful movements towards taking in a foreign body, actively engulfing and ingesting it, but rather the cell and the foreign body come together by chance and the taking in of the latter is a physical phenomenon. The number of bacilli taken in and the rapidity of the process appear to vary greatly with different types of cells. In this series of experiments the clasmatocyte was the most active; after that the giant cell, the non-granular white blood-cell, the granular white blood-cell, and the fibroblast, in the order named. When inside the cell the bacillus moves back and forth in the cytoplasm in the manner characteristic of included foreign bodies, and in course of time a vacuole forms around it, the bacillus being eventually destroyed.

A most interesting type of reaction on the part of living cells toward injurious substances has been studied by Mr. J. L. Wilson. He has found that the embryonic mesenchyme cell, when cultivated in weak solutions of copper sulphate and sodium arsenite, acquires in the course of two days a definite tolerance for strong doses of these two poisons. In dealing with the entire organism it is generally impossible to determine whether a given tolerance is intracellular or extracellular. In tissue-culture, however, this can be tested directly and in these experiments the tolerance was found to be intracellular. It is shown that ordinary embryonic mesenchyme cells have a certain amount of natural tolerance for the two inorganic poisons used and that an increased or acquired tolerance can be produced by growing the tissue in dilute solutions of the substances. The effect of the poisons was determined on the one hand by the extent and frequency of growths in the cultures and the maximal duration of life as compared with control cultures; on the other hand, by the time required to kill cells cultivated in these weak solutions by treating them with strong solutions, as compared with the time required to kill the cells in control cultures treated with the same solution.

Hydrogen-ion Concentration of Tissue-Cultures.

Bacteriologists have found that in growing bacteria there is an optimum hydrogen-ion concentration for their media and a limiting or final concentration at which growth activity ceases. In order to compare the metabolism of tissue-cultures with that of bacteria, and also to determine the effect of bacteria on tissue-culture growths, Mrs. Lewis and Dr. L. D. Felton have experimented with media of different concentrations and observed their relation to the activity of the growths. In order to test tissue-cultures for H-ion concentration, it was first necessary to devise a method by which the determination can be accurately made where there is only a small amount of fluid available for the test. A satisfactory procedure was worked out by Dr. Felton; this consists of a colorimetric method in which a piece of white opal glass is used as a background on which single drops of fluid are tested with a series of standard buffer solutions. It was found that cultures of embryonic chick tissue, when explanted into a solution having a hydrogen-ion concentration of 4 to 5.5, seldom showed any growth, while those in solutions having a concentration of from pH 6 to pH 9 usually showed abundant growth. The optimum hydrogen-ion concentration seemed to be about pH 7. Regardless of the initial hydrogen-ion concentration of the medium, where the solutions contained not more than 0.5 per cent dextrose, the cultures showing healthy and extensive growth tended to be neutral, those that had failed to grow usually became slightly acid, and those that had exhibited extensive growth and then degenerated were most frequently slightly alkaline. The final hydrogen-ion concentration varied, however, according to the amount of dextrose in the solutions. When 1 per cent or more dextrose was added to the medium, the cultures were often found to be acid when death took place. The addition of some dextrose to the medium proved to be necessary for a healthy growth of cells over a period of time longer than three days. There was some growth even with 5 per cent dextrose, but the cultures in solutions containing between 0.5 and 1 per cent exhibited the greatest proliferation of cells and remained healthy for the longest periods of time.

Adhesive Quality of Cells.

In studying the factors concerned in the migration of cells from the explant in tissue-cultures, Dr. W. H. Lewis calls attention to the important role played by the surface stickiness or adhesiveness which the cells exhibit for certain solids and for each other. Although we have been vaguely aware that many cells are sticky, the great importance of this adhesive quality in the various body-cells has been almost entirely ignored. It is now shown by Dr. Lewis that it is due to this quality that the form of most of our tissues and organs is maintained, and that, were it absent, there would be nothing to prevent our bodies from disintegrating. Without it, a multicellular organism could not exist. I shall speak later of his observations on the so-called syncytial relations supposed to exist in many tissues, in which he found evidence that these relations consist merely of adhesion of cell processes. In tissue-cultures he shows that migrating cells are so sticky for glass that they can be washed or centrifugalized without disturbing their attachment. He has thus far been unable to determine whether this quality is dependent upon the composition of the protoplasmic surface or upon some sort of substance that is secreted by the cell. In support of the latter theory there is the demonstrable occurrence around some cells of a cement substance that can be recognized by its power to reduce silver nitrate. He finds that most living cells in tissue-cultures exhibit a slight browning over their entire surface when treated with silver nitrate, while dead cells do not. This, however, may mean that silver nitrate is reduced by living protoplasm and not by any substance on its surface. It seems likely that the degree of stickiness may vary under different conditions. It may prove possible to measure the tenacity of the adhesion by the centrifugal force necessary to dislodge the cells, but so far even the high speed of the ordinary centrifuge fails to detach them. This property of cells to adhere to solids appears to explain why migrating cells in tissue-cultures follow solid supports, and it is probably erroneous to designate the phenomenon a tropism, as we have heretofore been inclined to do.

Nature of Mesenchymal Reticulum.

From the behavior of embryonic mesenchyme in tissue-cultures, Dr. Lewis has shown that there is no valid evidence for the view that it is syncytial in structure—that there is an actual fusion of the processes and transferal of material from one cell to another. On the contrary, the evidence indicates that it is an adherent reticulum and that the cell processes merely stick to each other by reason of the adhesive quality which he has shown they possess. From a mesenchymal explant presenting the typical picture of a supposed syncytium, cells can be seen to migrate out and completely isolate themselves from the reticulum of which they were a part. In this process one can watch the slow shifting of cells from one position to another and follow the withdrawal of processes which were adherent or in contact with the processes or bodies of the neighboring cells. The phenomenon of withdrawal and the formation of new processes is the same as when the processes adhere to the cover-glass, and there is never any evidence of tearing or rupture. Dr. Lewis has further shown that in cultures that have been washed in certain solutions the mesenchyme cells withdraw their processes and lose connection with the neighboring cells. Such retraction may proceed until all connections with the cover-glass are lost and the rounded cells fall to the lower surface of the drop. If, however, the cells retain their attachment to the cover-glass they may later send out new processes and a reticulum be again established. Sometimes a very slight disturbance may produce the withdrawal of processes and the rounding up of cells. It is clear that the physical factors of cohesion and surface tension or capillary attraction are constantly at work in altering the form of the cells and their processes, and it is in this direction that we must look for an explanation for the characteristic morphology of the different tissues.

Characteristics of Cell-Types in Growing Tissues.

In my last report I mentioned the progress that had been made by Dr. Lewis in the identification of the characteristics of the primary cell-types, as seen in cultures of growing tissues. During the past year he has completed a careful study of endothelial cells as they migrate out from embryonic chick liver-tissue. The liver at 96 hours' incubation presents the advantage of containing only two types of cells, the liver-cells proper and the endothelium of the sinusoids. No difficulty is encountered in distinguishing these two varieties of cells, the first growing out as a membrane and the other as a loose reticulum. Observers, working with the ordinary explant, have in the past had difficulty in identifying reticular radiating outgrowths and could not be sure whether, in addition to mesenchyme and fibroblasts, there were not some mesothelium and endothelium present. This uncertainty has in large part been removed by the detailed description and photographs which Dr. Lewis has published of known growths of endothelium.

In collaboration with Dr. L. T. Webster, Dr. Lewis has completed a study of wandering cells, endothelial cells, and fibroblasts in cultures from human lymph-nodes. The wandering cells were particularly interesting. After 2 or 3 hours' incubation they migrated from cultures of both normal and (in greater number) chronic inflammatory glands and were actively ameboid and phagocytic. These cells differ in size from the endothelial cells, but in structure and behavior they closely resemble them. Frequently transitional forms are found and it seems quite probable that the wandering cells are derived from endothelial cells.

Dr. M. J. Hogue has made a comparative study of living fibroblasts from the embryonic chick and salt-water amebæ obtained from the digestive tract of the oyster. By introducing the amebæ into the cultures of growing tissue-cells, it was possible to observe the reaction of the two kinds of cells to various vital dyes and pigment granules. In structure and behavior the ameba resembles the fibroblast. It is, however, not quite so large, the cytoplasm is denser, its outline is more definite, and it moves more rapidly. The presence of non-pathogenic bacteria is not injurious to the ameba, but is harmful to tissue-cells. On the other hand, amebæ are much more sensitive to vital dyes. When melanin pigment granules were put into hanging drops with the amebæ they were taken up by some and not by others, and it may be that the physiological condition of the ameba is a factor in this phenomenon. When an ameba takes in granules it does so in the same manner it takes in its food: it appears to push against the granule, whereupon the latter penetrates the ectoplasm. The granule must therefore be directly in the path of the advancing ameba. After the granules have entered the endoplasm they circulate freely through it. There is some tendency for them to clump, in which case a vacuole may form around them. These vacuoles are heavy and lag behind in the posterior part of the cell, and on coming in contact with the edge of the cell they break and discharge their granules into the surrounding medium. In watching the phenomena accompanying death of a cell, it is interesting to note that the ameba continues sending out pseudopodia after the nucleus and cytoplasm stain with methylene blue, which reaction in the case of tissue-culture cells we have regarded as evidence of cell death. For the ameba it is evident that motion, and not the reaction of the organism to stain, must be taken as the criterion of life.

The methods of tissue-culture have been applied to tissues of fish embryos by Dr. Pauline H. Dederer, who has found that they constitute a very favorable material for the study of living epithelial membranes. She has been able to show that both mesenchyme and ectoderm cells grow out from the explants in the form of membranes, the ectoderm spreading out as a thin layer upon the under surface of the mesenchymal membrane. In fundulus, however, the spreading activity of the ectoderm occurs only where it is in contact with mesenchyme, whereas mesenchyme readily grows out alone. The mesenchymal cells are actively ameboid and frequently exhibit characteristic, large, thin, fan-like expansions, by means of which they adhere to the cover-glass and to each other. The peculiarity in the growth of the ectoderm in fundulus may prove to have some bearing on the problem of the adhesive property of cells, which has been specially studied by Dr. Lewis.

Serosal Cells and Clasmatocytes.

For several years Dr. R. S. Cunningham has been conducting a series of experimental studies upon the omentum. In previous reports I have mentioned his work on peritoneal absorption and the phagocytic activity of the peritoneal mesothelium. More recently he has devoted his attention to the characteristics and relationships existing between the three great groups of cells which constitute the framework of the omentum—clasmatocytes, fibroblasts, and the serosal lining cells. An important step in advance has been attained in his success in the differentiation of the mesothelial lining cell from the clasmatocyte. He accomplished this by testing the reactions of serosal cells lining the peritoneal and pleural cavities to various types of stimuli and found that their reactions are entirely different from those of the clasmatocytes, the fundamental behavior of the former being adapted toward secretion, while the latter is toward phagocytosis. The serosal cell may take up particles of dye, it may detach itself and become free, but it does not become a clasmatocyte. Dr. Cunningham shows that in reality it is more closely allied to the fibroblast than it is to the clasmatocyte. It can, however, be differentiated from the fibroblast by the institution of mild irritations, under which circumstances the two types of cells clearly differ, both in form and the manner in which they store vital dyes.

In another study, Dr. Cunningham has found that the mesothelial cells from different areas of the peritoneal surface exhibit certain peculiarities in the manner in which they store vital dyes, sufficient to classify them in groups, although they all conform to a general type. The principal groups are: (1) general serosal mesothelium covering intestine, body-wall, liver, and diaphragm; (2) mesothelium covering the omentum; (3) mesothelium covering the spleen. The germinal epithelium covering the ovary was found to store vital dyes in an especially characteristic manner. Each cell contained a large amount of dye which was assembled in the infranuclear zone, instead of forming a perinuclear rosette, as occurs in mesothelium. In well-stained animals the dye granuales filled the entire portion of the cell between the nucleus and the basement membrane.

Having acquired in his previous study a familiarity with the reactions and characteristics of the living cells of serous membranes, Dr. Cunningham has been able to trace them after they become detached, and thus he has contributed to our knowledge of the source of the cells found in serous exudates under normal and pathological conditions. He finds characteristic, desquamated serosal lining-cells in the serous exudates at all times during a chronic irritation. They degenerate rapidly and do not become clasmatocytes. The clasmatocytes are derived from just one source, that is, the pre-existing clasmatocytes of the neighboring subserosal tissues. The omentum is a great storehouse for these cells, but they are present in all peritoneal territories. His experiments show that all the polymorphonuclear neutrophiles, part of the eosinophiles, and part of the monocytes that appear in inflammatory exudates are derived by emigration from the blood-stream, while part of the monocytes and possibly some of the eosinophiles are derived from the seat of the inflammatory process.

The completed paper on the distribution of clasmatocytes in various organs, prepared by Dr. C. S. Beck, has appeared during the year. An account of his observations was given in the Year Book for 1919. The study of Professor A. M. Reese on the structure and development of the integumental glands of the crocodilia has also appeared in its completed form.

VASCULAR SYSTEM AND CHROMAFFIN GLANDS.

Blood and Blood-Vessels.

In the report of this Department for the year 1920 reference was made to the work of Professor F. R. Sabin upon the origin of the vascular system, as observed in the living chick blastoderm. During the past year these investigations have been continued, and with further improvement in methods Dr. Sabin has been able to study the living membranes in the natural state and under the influence of vital dyes for the first 7 days of incubation. With the new technique she has made important observations on the origin and differentiation of blood-cells and has brought the study of the blood into the field of experimental cytology where the anatomist and physiologist may meet on common ground. In her previous study she found in the living chick that on the second day all the primitive blood-cells become erythroblasts and that their genealogy is angioblast directly to erythroblast, or angioblast, endothelium, erythroblast. In carrying the study to older, vitally stained chicks, she finds that the primitive red cell shows a characteristic granulation; on the second and third day it takes the form of vitally stainable specific granules and rods which form a wreath around the nucleus and completely fill the cell. As the cytoplasm increases, this granulation is thinned out and the basophilic, finely granular cytoplasm becomes more and more evident. Some specific granules, however, are found in all of the red cells up to the time of hatching, although the basophilia of the cytoplasm disappears. These reactions give us a specific criterion for distinguishing the primitive red cell from the other types of blood-cells; furthermore, one can recognize how primitive a given cell is by the amount and arrangement of its granules. This should be of great advantage clinically, where one is studying conditions in which blood is regenerating. It will be necessary now to work out the exact stages of development of the vitally stainable granules in the human embryo, and we can then estimate just how primitive are the young cells found in the circulation for each phase of regeneration.

The first white cell makes its appearance on the third day of incubation; this is the monocyte or transitional cell. It develops within the vessel from the endothelium, acquiring its characteristic structure before becoming detached from the wall of the vessel. At the same time the clasmatocytes can be seen arising from the endothelium on the outside of the vessels, being identical in form with the monocytes. In other words, Dr. Sabin shows that the monocytes of the blood and the clasmatocytes of the connective tissue are derived from the same epithelium and are identical, except that one is intravascular and the other extravascular. They are afterward interchangeable, however, for clasmatocytes have been seen to enter the vessel and monocytes to pass out. The granulocyte is derived from the mesoderm outside of the vessels and can be first seen on the third day of incubation. At first it resembles a single angioblast, but as soon as division takes place it can be differentiated; two granulocytes separate, whereas two angioblasts remain together. This whole process and the subsequent differentiation and entrance of the granulocyte into the vessels can be watched in the living preparations. Up to the seventh day there is no evidence of the formation of lymphocytes in the yolk-sac membranes. They are found, however, in the circulating blood on the fourth and fifth days. Their origin must be looked for in the body of the embryo.

In studying the blood-vessels of the bone-marrow, Mr. C. A. Doan has discovered that, in addition to the large, thin-walled venous sinusoids that form the principal functioning vascular bed of the marrow, there is an extensive inter-sinusoidal capillary plexus hitherto unsuspected. This plexus is apparently collapsed in its normal state, but is capable of distention under the conditions of the injection technique. A preliminary account of Mr. Doan's observations has appeared and the complete report of his study is now in course of publication.

Lymphatic Vessels.

Working in a field in which such notable results have been accomplished by Professor Sabin and Dr. Cunninghan, Dr. F. C. Lee has devised a satisfactory intrathoracic method for the ligation of the thoracic duct in the cat. Animals upon which the operation was performed have lived as long as 66 days, apparently unaffected, and it is thus clearly evident that the integrity of the thoracic duct is not essential to the life of this animal. Where the ligation did not include the periaortic plexus, a collateral lymph circulation was established to the right thoracic duct. Where the ligation was complete, the investigator found well-defined lymphatico-venous anastomoses existing between the thoracic duct and the azygos vein. It is clearly evident, therefore, that these connections must be taken into consideration in any future study of fat absorption. In reviewing what is known regarding the embryology of these structures, Dr. Lee does not find an adequate basis for their explanation.

In the course of the preceding investigation, Dr. Lee obtained a specimen which was so injected as to reveal the distribution of the lymphatic vessels in the wall of the aorta. In view of our meager knowledge concerning the lymphatic drainage of arterial walls, this successful specimen has proved worthy of careful study. Dr. Lee finds that there is an extensive lymphatic plexus at the junction of the media and adventitia and that it anastomoses with a more superficial plexus of larger lymphatic vessels.

Abdominal Chromaffin Body.

From the observations of earlier investigators, we are familiar with the size, shape, number, color, and distribution of the abdominal chromaffin bodies in the dog, cat, rabbit, and man, but regarding the function of these apparently important structures and their relation to the medullary substance of the adrenal glands, which they so closely resemble, we know very little. With the purpose of obtaining more definite information on this subject, Doctors Wislocki and Crowe have carried on a series of experiments in which varying proportions of the adrenal glands were removed and graded radium emanations applied to the parts of the gland that were left in position. The resultant changes in the abdominal chromaffin body were then observed. In dogs in which the adrenals had been destroyed it was found that the abdominal chromaffin body at the time of death of the animal showed every evidence of normal or slightly increased activity, and the investigators deemed it probable that it is capable of performing the secretory function normally subserved by the medulla of the adrenal. On the other hand, there is conclusive proof that the cortex of the adrenal is necessary to life.

In this connection mention should be made of the improvements in the technique for demonstrating chromaffin tissue which have been devised by Dr. Wislocki, whereby the presence of this tissue can be determined with greater clearness and precision. With this technique he has been able to show the presence of chromaffin bodies of macroscopic size in the retroperitoneal tissue of a number of mammals (opossum, squirrel, guinea-pig, and monkey) in which previous observers had failed to find them.

NERVOUS SYSTEM.

Development of Medial Wall of Forebrain.

The cerebral vesicles in the human embryo exhibit on their medial wall a transitory fissuration, the significance and even the existence of which has been the subject of much controversy among embryologists and neurologists. Dr. Marion Hines, using the material in the University of Chicago collection together with our material, has been able to give a clear account of this phenomenon. She has shown that an arcuate or hippocampal fissure does exist and that it is delimited by a characteristic histological morphology of the neural wall. She has discovered that at a certain stage in development it is coextensive with the hippocampal primordium and that, as cortical differentiation proceeds, that portion of it which lies anterior to the velum transversum disappears. Posterior to the velum, however, it persists as the adult fissura hippocampi. The whole hippocampal region, together with the adjacent parts of the telencephalic vesicle, is included in this study, which will make it of fundamental value to the brain anatomist.

First Evidences of the Eye and Ear.

Professor G. W. Bartelmez, of the University of Chicago, in conjunction with Dr. H. M. Evans, undertook in 1915 a study of young human embryos during the period of somite formation. The work is now nearly finished and is being prepared for publication. Certain features of the early history of the nervous system have been made the subject of an independent study by Dr. Bartelmez and his paper has recently appeared. In this he deals especially with the origin of the otic and optic primordia, basing his observations on 12 normal human embryos, of stages ranging from 3 to 16 somites. His account gives us for the first time an adequate picture of the earliest stages in the development of these sense organs. He finds that the acoustico-facial ganglion is unquestionably derived from the wall of the definitive neural tube, being delaminated from the dorsal part of the neural fold before the process of tube formation is completed. As for the geniculate ganglion, he finds that it is derived, in part at least, from the epibranchial placode of the hyoid arch. His observations indicate that the gustatory ganglion cells of the ninth and tenth cranial nerves, as well as those of the seventh, are derived from epibranchial placodes, whereas the other elements are probably derived from the neural crest. Owing to the conflicting results obtained by investigators from experiments in the production of cyclopia, the observations of Dr. Bartelmez on the origin of the optic vesicles are of particular interest. He finds that from the outset these vesicles are lateral in position and are not of median origin. The development of the otic primordium before the optic in man appears to be unique. It is explained partly by the fact that the otic plate is formed at an extraordinarily early period, being recognizable at 2 to 3 somites, and partly by the fact that the optic primordium is differentiated relatively later than in most other mammals.

Cerebrospinal Fluid.

In previous reports mention was made of the studies of Professor L. H. Weed upon the effect of intravenous injections of hypertonic and hypotonic solutions upon the pressure of the cerebrospinal fluid. The fact that in this way one can, to a considerable extent, control the brain volume has given an immediate practical value to these observations and has led to their clinical application in man. During the past two years Dr. Weed, in conjunction with Dr. Walter Hughson, has extended this series of experiments to include observations upon the arterial and venous pressures in relation to the cerebrospinal fluid. With a technical control that permitted the determination of the effect of the manipulative procedure upon the pressure of the cerebrospinal fluid, they have been able to obtain some knowledge of the range and variability of the normal pressure. From their studies it is shown that the pressure of the cerebrospinal fluid practically always exceeds that of the superior sagittal sinus (5 to 50 mm.). They also found that alteration in the intracranial venous pressure effected alterations in the pressure of the cerebrospinal fluid in the same direction but of lesser magnitude, and conversely, alterations in the pressure of the cerebrospinal fluid caused changes in the sagittal venous pressure of lesser extent but in the same direction. As for the intracranial arterial pressure, this is evidently a factor of importance in the maintenance of the pressure of the cerebrospinal fluid, though slight or slowly effected changes in the arterial tension have but little influence upon it. Thus, though the pressure of the cerebrospinal fluid is dependent upon the intracranial venous and arterial pressures to the extent of being influenced passively and in the same direction by both, yet it is relatively independent of each of them, in that normally it maintains an individual, fairly constant level far below that of the intracranial arteries and somewhat above that of the intracranial veins.

By introducing hypertonic and hypotonic solutions of various concentrations into the blood-stream, these investigators have been able to study the general systemic and intracranial vascular alterations that occur under these conditions, and there is thus afforded a unique opportunity for a study of the mechanisms which normally control the pressure of the cerebrospinal fluid. Analysis of their data demonstrates that alterations in the pressure of the cerebrospinal fluid can be effected and maintained independently of change in the intracranial and peripheral vascular pressures. These changes in pressure must be explained by the alteration of the osmotic pressure of the circulating blood. Where the volume of the blood is increased by the injection of a considerable amount of isotonic solution, there is a brief rise of the cerebrospinal fluid pressure, long enough for the organism to compensate for the increased volume of fluid. When, however, the volume of circulating blood is increased and at the same time its salt-content relatively diminished by the intravenous injection of distilled water, there is a prolonged increase in the pressure of the cerebrospinal fluid, accompanied by an increase of venous pressure of lesser degree and duration. We are here concerned with two processes of adjustment: (1) the giving off of water to the tissues with attraction of salts from them, as evidenced by the increased brain volume and pressure of the cerebrospinal fluid; (2) compensations in the vascular bed, indicated by the return of the vascular pressure to normal levels, while the pressure of the cerebrospinal fluid remains high. The intravenous injection of strongly hypertonic solutions causes a prolonged and profound fall in the pressure of the cerebrospinal fluid, preceded usually by a sharp rise. Here the chief increase of fluid volume in the circulating blood is due to the attraction of water from body-tissues, to which is to be attributed the decrease in brain volume and the reduction of pressure of the cerebrospinal fluid.

Working with Dr. Weed, Dr. J. C. Nañagas undertook to determine the effect of intravenous injections of hypertonic and hypotonic solutions on the brain bulk and the pressure of the cerebrospinal fluid in the dilated cerebral ventricles of hydrocephalic kittens. Though the pressure in the kittens was considerably higher than in normal animals, it could be decreased or increased at will and in some cases even reduced below zero. Subsequent histological examination of the material yielded the important observation that the increased absorption of the ventricular fluid occurring after injections of hypertonic solutions takes place through the ependyma into the underlying capillary network. There is no evidence of absorption by the choroid plexuses.

During the year a review has been prepared and published by Dr. Weed, outlining what is now known concerning the cerebrospinal fluid in its embryological, anatomical, and physiological aspects. Such a complete and authoritative account should prove of very great value to those who have occasion to concern themselves with this important body-fluid.

The Cranium as a Closed Box.

As mentioned in the last Year Book, Dr. Weed and Dr. Hughson have been carrying on a series of experiments to test the correctness of the hypothesis that the cranium and vertebral canal constitute a rigid and closed mechanism. That it was possible to obtain negative pressures within the subarachnoid space demonstrated the essential truth of the "closed box" principle, but the phenomenon might conceivably have been due to other factors than the mere rigidity of the cranial case. These investigators have, however, completed a series of experiments that establish the validity of the Monro-Kellie doctrine beyond further doubt. This was shown by demonstrating first, that with the bony skull removed over one cerebral hemisphere, repeated intravenous injections of strongly hypertonic solutions failed to reduce the pressure of the cerebrospinal fluid to negative values; whereas, when the opening through the skull was rigidly sealed, negative pressures could be obtained, and on removing the sealing device there was an immediate rise of pressure to positive readings.

Localization of Cutaneous Nerves.

Dr. Hughson has perfected a method for the accurate localization of cutaneous nerves, which is proving of service both as a teaching method and for clinical purposes where it is necessary to anesthetize defined territories.

REPRODUCTIVE SYSTEM.

Function of Fetal Membranes.

In the report of last year reference was made to the studies of Dr. R. S. Cunningham on the fluid and salt interchanges between mother and fetus and also of his important discovery that the chorionic ectoderm is unequally permeable to different salt solutions—namely, sodium ferrocyanide and iron ammonium citrate—which diffuse through inert membranes at approximately the same rate. This indicates that a physiological activity takes place in the placental membrane in the nature of a breaking down and a resynthesizing of substances finally intended for fetal consumption. Dr. Cunningham has continued this work and has studied the reaction of the placenta of the cat after more extended exposures to these solutions than those reported last year. He has also controlled the interactions of the two salts by studying them separately.

He found that prolonged injections of sodium ferrocyanide and iron ammonium citrate into the maternal blood-stream, when given together, produced in the placenta the same general results that have been described for the shorter experiments, the most striking feature being the appearance of the syncytial layer of the chorionic ectoderm, in which the Prussian blue was precipitated within the cytoplasm adjacent to the maternal endothelium. The border of the chorionic ectoderm adjacent to the fetal vessels always remained free of the precipitate. It is interesting to note that in these longer experiments there was a slight precipitation of Prussian blue in the living placenta. In bits of tissue that had not been exposed to any acid reagent, a few granules of blue could be found between the maternal endothelium and the chorionic ectoderm and others in the syncytial layer of the chorionic ectoderm. It is clear that there is some factor that brings about a partial precipitation of the Prussian blue during the life of the cell. In the experiments where iron ammonium citrate was given alone, it was found that ferric iron did not reach the tissues of the fetus. It was only where a very large dose was administered that there was a questionable trace of iron found in the fetal urine. As a final precaution, the factor of anesthesia was taken into account and it was found that where urethane was used the results were the the same as under ether anesthesia and in decerebrate animals. From Dr. Cunningham's work it seems clear that in the placenta we have a regulating mechanism which is capable of controlling at least the passage of iron-containing substances, the decomposition of which is necessary for their preparation for fetal use.

With the purpose of obtaining more precise knowledge concerning the functions of the fetal membranes in the developing egg of the hen, Dr. G. B. Wislocki injected with trypan blue a large number of eggs of 11 days' incubation, orienting his injecting needle so that each of the various compartments was sure to be reached in a certain number of eggs. On the thirteenth day the eggs were examined and the effect of the dye on the different structures was observed. When placed in the yolk-sac the dye was taken up by the lining epithelium, particularly in the region of the area vasculosa, and, penetrating the basement membrane, reached its final destination, the groups of cells surrounding the vessels of the yolk-sac wall. The endothelium lining the vessels remained unstained and none of the dye reached the embryo, not even through the yolk-stalk into the intestine. When trypan blue was injected into the allantoic sac it colored the allantoic fluid uniformly dark blue, but was not taken up by the wall of the sac, nor did any of it reach the embryo or its other membranes. This accords well with the view that the allantois serves only as a reservoir for excretory products. When injected into the amniotic sac the dye was taken up by the amniotic membrane and was found in the stomach, intestines, trachea, and primary bonchi, indicating that the amniotic fluid is swallowed by the embryo. When trypan blue was injected into the mesoblastic tissue, vital staining of nearly all parts of the embryo occurred. It was found in greatest abundance in the Wolffian bodies, in the form of fine granules in the epithelium lining the uriniferous tubules. Evidently, this is the main pathway of excretion at this period. The next in order of abundance of dye was the liver, where the granules were found in nearly all of the endothelial cells lining the sinusoids and the terminal branches of the portal vein. There was none in the liver-cells. The dye was found in small amounts in the cells lining the vascular channels of the spleen and in the mononuclear cells of the splenic sinuses. Except in these three organs, it was encountered only in traces, and not infrequently in the connective tissue, in cells resembling clasmatocytes.

Uterine Ciliation.

A description has heretofore been given of the studies of Dr. G. W. Corner on the changes in the mammalian ovary and uterus during the successive events of the reproductive cycle. With the familiarity thus acquired of cyclic changes in the uterine endometrium, it has been possible for Dr. Corner and Mr. F. F. Snyder to make an important contribution regarding uterine ciliation, which serves to prove its non-correlation with the time of ovulation and the wandering of the ova. They have been able to show that cilia are not present on the surface epithelium of the uterus of the pig at any period of the estrous cycle. In the glands of the uterine mucosa, however, cilia are always present and appear to be equally active and numerous at all periods of the cycle. The observations were made upon bits of uterine and tubal mucosa taken from freshly killed animals and flattened down under a cover-slip. Under these conditions, with low powers of the microscope, the cilia could be seen actively beating, the motion continuing for several hours even at ordinary room temperature and without the addition of any special fluid. Sections of fixed tissue taken from the same material showed the characteristic histological structure of the cilia. In this manner it was possible to demonstrate that cilia are present in the tubes and in the uterine glands, but never on the surface of the uterus. Furthermore, there is never any significant variation in the number or activity at different stages of the cycle. We must therefore assume that, in the uterus of the pig at least, the cilia can play no important part in the transport of the ova, as has been frequently suggested, but must be associated with some other function. In fact, from what we know from Dr. Corner's studies on the internal migration of ova, the latter are able to move against any currents produced by the uterine cilia, whatever the direction of these currents may be.

Ovarian Follicles.

Working with Dr. Corner, M. S. and A. F. Guttmacher have studied the wall of the mature Graafian follicle of the sow and have been able to prove, by physiological measures as well as by morphological criteria, that there is an abundance of typical smooth-muscle cells in the theca externa. In some places these cells form solid bands of muscle, in others they exist only in scattered groups in the follicular wall. It is interesting to note that where the follicle has been freshly ruptured the arrangement of the muscle-fibers suggests that they in some way take part in the rupture; that is to say, they do not remain as a passive membrane on the periphery, but project along with the other layers as finger-like processes into the contracted follicular cavity. Proof that these fibers function as smooth muscle was established by cutting out a strip of the living follicular wall and suspending it in a warm bath of oxygenated Locke's solution, so that by means of a writing lever an accurate record of its contractions could be obtained on a smoked drum. Under these conditions, when the strip was stimulated by the addition of a solution of barium chloride, records were obtained which were typical of smooth muscle.

These investigators succeeded also in demonstrating the presence of autonomic nerves with typical motor endings in juxtaposition to the smooth-muscle cells. Furthermore, they have shown that the innervation is similar to that of the musculature of the intestine; that is, the nervous mechanism of the follicle responds to the action of a drug which stimulates fibers of the true sympathetic system, causing a relaxation of the smooth-muscle fibers. On the other hand, by the use of other drugs, the presence of a para-sympathetic innervation and the contraction of the ovarian musculature were demonstrated.

From these experiments it is not possible to say that the smooth-muscle of the ovary is responsible for the periodic rupture of the follicles. The investigators were not able to produce contractions sufficient to induce rupture by any of the methods of stimulation used. They worked with excised organs and it is possible that, if similar experiments could be conducted in the living animals, fruitful results might be attained. At any rate, it is apparent that the hypothesis of Hensen, that rupture is induced solely through increased arterial tension, is incorrect. Repeated experiments with mature follicles, in which injections of the ovarian and uterine arteries were made under great pressure, failed to result in a single instance of rupture of the follicle.

ANOMALIES IN DEVELOPMENT.

Zygodactyly and its Inheritance.

The occurrence of anomalous webbing between the toes has been studied by Dr. A. H. Schultz with reference to its embryology and its relation to heredity. He finds that it is normally present in early development and that in the rare cases where it persists it is to be regarded as a developmental arrest. Where it shows a familial incidence, it does not skip a generation. The cases thus far reported indicate that the chance for the female to transmit webbed toes is very much less than for the male, and furthermore, female progeny is less apt to inherit the condition than male progeny. It is of interest to note that zygodactyly of the foot seems always to occur between the second and third toes. The condition in mammals is not restricted to man; it is found in several groups of marsupials and in the siamangs (apes from Sumatra and the Malay Peninsula). In these animals skin fusion between the second and third toes is a constant occurrence. When the fusion is present in man the tendon of the long extensor muscle for toes II and III is unsplit for an unusually long distance.

Bregmatic Fontanelle Bones.

Special interest attaches to the bregmatic bones for the reason that in a few mammals they seem to be almost the rule, while in a large majority of mammalian skulls their occurrence is exceedingly rare and in some they have never been found. Through the cooperation of the National Museum at Washington and the American Museum in New York, Dr. Schultz has been able to supplement his own material and thereby carry out a study of variations in number, size, and shape of these but little-understood bones in different mammals. It would appear that they are to be regarded as a new acquisition in mammals, in which here and there the normal skull bones prove insufficient to close the fontanelle in due time. Any theory regarding the bregmatic bones, however, must await substantiation until our knowledge of the factors involved in the normal closure of the great fontanelle in mammals has been lifted from its present rudimentary state.

GENERAL.

During the past year, from July 1, 1921, to June 30, 1922, there were 589 accessions to our collection of human embryos. Among them are some very valuable young specimens which will serve to fill some of the gaps existing among our early stages. At the present time, owing to the limitations of our storage facilities, we are not able to preserve all the material received. However, measurements and records are kept of all specimens for the purposes of statistical studies. A certain amount of relief from our cramped condition has been secured for the coming year through the courtesy of the Johns Hopkins Medical School, which has placed at our disposal four rooms in the Hunterian Building on the floor below the one in which we are now located. This will not only provide additional storage room, but will also give us two research rooms which are needed for visiting investigators.

We are fortunate in securing the services of Dr. Chester H. Heuser, Associate in Anatomy of the Johns Hopkins University, who joined our staff on July 1, 1921. Dr. Heuser received his doctorate under Professor Minot, with whom he acquired a fundamental training in mammalian embryology. He subsequently continued his studies in embryology at the Wistar Institute, where he remained up to the time of coming to Baltimore. Dr. Heuser has assumed charge of the examination and classification of new accessions.

As has been our experience in previous years, several visiting investigators have spent longer or shorter periods working with us as space permitted. For the most part they have come either to take advantage of our embryological collection and associated facilities or to acquaint themselves with the more recent work in tissue-culture that is being carried on by W. H. and M. R. Lewis. The profit from these visits is not all one-sided, for such contact with workers from other laboratories is a source of stimulation, suggestion, and criticism and is of great value to our own local group. Professor Bartelmez, of the University of Chicago, has worked with our younger embryological specimens and has practically completed a comprehensive study of the human embryo for the period between 2 and 20 somites. Dr. H. H. Woollard, of the University College, London, has studied the development of the blood-vessels of the arm. His visit here was made possible through the generosity of the Rockefeller Foundation. Professor C. L. Davis, of the University of Maryland, has completed his study of a human embryo of 22 somites. Dr. E. D. Congdon, on a year's leave of absence from the Leland Stanford University, has traced the history of the aortic arches in the human embryo. Professor H. D. Senior, of the Bellevue Hospital Medical College, New York, has consulted our material in connection with his work upon the development of the blood-vessels. Dr. Erwin F. Smith, of the U. S. Department of Agriculture, and his associate, Dr. Brown, have studied the methods of tissue-culture with the view to their application to investigations in plant pathology. Dr. J. C. Baldwin, of the Department of Pediatrics, Johns Hopkins Hospital, has studied abnormalities in the growth of the fetus. Dr. W. F. Reinhoff, of the Department of Surgery, has conducted some experiments in the growth of kidney tissue with the tissue-culture technique. Dr. F. P. Johnson, of the Department of Urology, has modeled the fetal female urethra. Dr. M. B. Wesson, of San Francisco, formerly of the Department of Urology, has continued his embryological studies of the male perineum. Dr. H. S. Willis, of the Department of Medicine, has cooperated in a study of the effect of avian tubercle bacilli upon tissue-culture growths. Dr. C. C. McCoy, of the Department of Pathology, has determined the power of survival of cells after the death of the animal. Dr. D. T. Smith, who enters the Department of Pediatrics this fall, has continued his studies on pigment-cells. Miss E. B. Finley has studied the histogenesis of blood-vessels. D. M. Rioch, J. L. Wilson, M. Thompson, J. T. Bauer, and K. S. Oliver, all students in the Johns Hopkins Medical School, have worked with Professor and Mrs. Lewis in connection with their investigations on tissue-culture. Most of these studies have resulted in papers that are now either in preparation or in the hands of the publisher; they will be described more completely at some subsequent time. A few have been mentioned in the main body of the present report.

DEPARTMENT OF GENETICS.[1]

C. B. Davenport, Director.

GENERAL STATEMENT.

In its second year following reorganization the work of this Department has shown itself especially productive, justifying the hopes we have had that the combination of research in plants, animals, and man would be a fruitful one. Despite the large extent of subjects covered, all investigations fall under the one subject of inquiry: the gametic constitution, its mechanism, its combinations, and their somatic manifestations.

While all investigations have been unusually prolific, three are sufficiently outstanding to warrant special mention. These are, first, the experimental modification of the germinal constitution in mice; second, the rapid opening up of the phenomenon of aberrations in the chromosome-complex of *Datura* and the mutations that result therefrom; and third, new light on the control of sex and the sex-ratio.

As modern genetics has been bringing to light the dependence of somatic form and structure on the architecture and number of chromosomes, the urgency of the problem of the experimental control of the structure and number of chromosomes has become more pressing. Indeed, not until such control is secured may the era of experimental evolution strictly be said to have been entered upon. While attempts to modify the germ-plasm may have been more or less successfully made by Stockard and McDowell with alcohol, by Guyer with cytolysins, and by others, yet none of these have yielded a type of inheritance that lent itself to Mendelian analysis. In this respect the results obtained by Dr. Little, with the cooperation of Dr. H. J. Bagg, are much more clean cut. By subjecting mice to X-rays some grandchildren were obtained with abnormal eyes. These were then bred from and subjected to the ordinary genetical analysis. Apparently a single-gene mutation affecting the eye has been induced, and this reappears in subsequent untreated generations like a Mendelian recessive. Moreover, in one or more chromosomes other genes have apparently been set mutating so that abnormal heads, appendages, trunk, and epidermal organs are appearing. Inasmuch as the control of mutation is the experimental control of evolution, outside of and beyond the ordinary operations of hybridization, the possibilities of such experimental control (now in its infancy) can not be overestimated.

The second outstanding result is the further analysis of the variations of the chromosomal complexes and their corresponding somatic mutation. Variations in the number of chromosomes had, indeed, been seen by others; that "non-disjunction" was accompanied by somatic modifications had been shown by Bridges in *Drosophila*; but it has remained for *Datura* to reveal in the hands of Blakeslee and his associates, Belling, Farnham and others, an extensive system of inter-chromosomal mutation and corresponding somatic change the like of which had been entirely unknown.

The studies of Morgan, Sturtevant, Bridges, and Muller of gene mutation and of Blakeslee and his associates on holochromosomal mutation, as well as those of Metz on chromosomal homologies and chromosomal fragmentation, elevate *the chromosome* to the position of the principal mechanism of heredity and evolution. It illustrates the slowness with which new discoveries filter into popular knowledge that the very name of the chromosome—so fateful for mankind and civilization—should still be almost unknown outside of genetic circles and sometimes insufficiently regarded and recognized even by active biologists. To the geneticist, however, the chromosome with its genes affords another precious link between the complex phenomena of the development of the individual on the one hand and the constitution of matter on the other. There is certainly much in the phenomena of gene mutation with its prevailing recessive tendency, its measurable rate of occurrence, and its predictability, that shows at least many points of similarity to the gradual changes, by loss, of the salts of the uraniun-radium-lead series.

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[1] Situated at Cold Spring Harbor, Long Island, New York.

In earlier reports much emphasis has been laid on the fundamental biological phenomenon of sex, and regret has been expressed that we were able to enter so inadequately into that field, for whose investigation we have special facilities. Yet marked progress has been made during the current year in an understanding of the nature of sex. For some years Dr. Riddle has demonstrated that the pigeon's egg that is destined to produce a female has more stored food material than an egg that is destined to produce a male. He has been inclined to conclude that the special metabolic environment of the early embryo was the cause of its becoming a female. Other biologists have emphasized the rôle of the sex-chromosome in determining sex. But the two views are not irreconcilable, inasmuch as the chromosomes are, doubtless, regulators of the metabolism of the cell; but other conditions may control cell metabolism and in so far sex. Dr. Riddle, however, has forged a new link in the evidence of the influence of metabolism on sex. Pigeons forced to lay excessively lay an excess of large, female eggs. Ovulation is associated with a functional enlargement of the suprarenal glands; suprarenal hyperactivity causes an increase of sugar in the blood. This provides more food for the eggs at the time of maturation. This is probably why more large (or female) eggs are laid during the period of enforced, excessive ovulation.

In Cladocera, also, progress has been made in isolating the factor or factors that bring about the production of males. The evidence indicates that the determination of sex takes place at the time of maturation of the parthenogenetic egg and that something in the water of overstocked culture-vials influences the processes of maturation so that some of the eggs will develop into male individuals.

The opportunities for investigation in the field of genetics are limitless, and the field touches vast human interests in agriculture, physiology, and applied eugenics. In the past we have prospected rather widely, with the aim of finding the best lodes to work. With our limitation in resources and with fertile subjects of research in hand, it is clearly advantageous to concentrate upon a few of the most productive of them. Thus we are gaining in unity, and profit by the mutual criticism and cumulative ideas that come from cooperation.

DETAILED REPORTS ON INVESTIGATIONS IN PROGRESS.

INTERCHROMOSOMAL MUTATION.

The work of the past year has extended the studies on mutations in the jimson weed (*Datura*) due to variations in chromosome number and probably due in turn to abnormalities in the process of formation of the gametes. This work has become so broad as to require the cooperative studies of a number of persons and we have been so fortunate as to secure the collaboration during the summer time of investigators who are connected primarily with other institutions. Besides Dr. A. F. Blakeslee, who has charge of these experiments, Dr. John Belling, who is making the principal cytological studies and Mr. M. E. Farnham, who has immediate charge of most of the work in the greenhouse and the field, we have had the cooperation of Professor E. W. Sinnott, of the Connecticut Agricultural College at Storrs, who has been studying the internal anatomy of the Daturas and as a result of that study finds he is able to recognize the majority of the mutants from an examination of their tissues; of Dr. John T. Buckholz, who has been studying, with the use of a newly perfected method, the growth of pollen-tubes and abortion of ovules as problems in developmental selection. Miss Dorothy Bergner and Miss Lois Lampe have helped respectively in making chromosome counts, in counting pollen, and assisting in hybridization. Mr. J. L. Cartledge has again acted as summer recorder.

In addition to the securing of further data upon the breeding behavior of types mentioned in the Year Book for 1921, pages 104 to 107, work has been done on certain new types which have been discovered. These may be treated collectively under the heads of balanced and unbalanced types.

Balanced Types of Datura Mutants.

One of the most fundamental doctrines of genetical biology is that the germ-cells before union contain half of the number of chromosomes of the fertilized egg or developing embryo (zygote). It has been assumed that, except in the case of parthenogenetic species, the soma must contain chromosomes in sets of two, one of paternal and one of maternal origin. One of the most notable discoveries of the year was the finding of five haploid or $1n$ plants, which appeared in the offspring of parents treated with cold in an attempt to induce mutations by external stimuli.

They were early recognized as new forms by external appearance, but more definitely by the condition of the pollen. The 12 chromosomes in their pollen mother-cells undergo a pseudo-reduction into $8+4$, $7+5$, etc., a process which suggests that a paired condition of the homologous chromosomes is not necessary for the reduction division in gametogenesis. Occasionally a pollen mother-cell fails to undergo reduction, and normal $1n$ grains are produced which apparently function like pollen from a normal diploid ($2n$). The few seeds we have obtained this season from selfing our haploids ($1n$) have given rise to diploids ($2n$) which are of considerable genetic interest, since they furnish a new method of rendering a stock homozygous without long inbreeding. Coming from plants with but a single chromosome in each chromosomal set, the paired chromosomes in each set of these diploids must be identical. Hence, barring new mutations, diploids derived from a given haploid must be completely homozygous, as alike as identical twins.

A paper on inheritance in tetraploid Daturas now ready for publication gives records of color in over 37,000 individuals and forms the basis for the conclusion that the ratios of purples to whites obtained from combining the various genetic types are brought about by a random assortment of chromosomes in the purple-white chromosome set.

Dr. Blakeslee has reported further as follows:

"Tetraploidy may have been of influence in evolution. An experimental proof of this belief would probably demand the transformation of a tetraploid with 12 sets of chromosomes each into a double diploid with 24 sets of 2 chromosomes each. A single plant last year appeared to be duplex for the purple and armed factors and to give 15:1 ratios for both these two factors in its offspring, a result to have been expected if the plant had been a double diploid. Plants in the next generation, however, gave normal ratios characteristic of typical tetraploids and showed that, if the plant were in fact a double diploid, the condition had not been transmitted to its offspring.

"The assumption seems reasonable that competing plants in nature are diploid, although few forms have been critically tested and proven to be diploid rather than tetraploid either by breeding or cytological evidence. In order to discover if tetraploids are capable of establishing themselves in nature, we planted out on Goose Island this spring a score of tetraploid plants of *Datura*, and plan to leave them to seed themselves in competition with other species.

"The most expeditious way to obtain the full range of different $(2n+1)$ mutants in a given stock is by crossing triploids $(3n)$ by diploids $(2n)$. Triploids we have never identified in the offspring when both parents were diploids, but they may be obtained by crossing tetraploids with diploids. We are interested, therefore, in having possibly discovered a method of identifying tetraploids in the seed stage. Seeds of tetraploid plants average distinctly larger than those of diploids and from the few large seeds out of many thousands examined from our chief main line one already has given rise to a tetraploid plant, the first that we have discovered in this line during the last 7 years in which it has been extensively planted. It is not impossible that by a similar method of selecting large seed from tetraploids $(4n)$ we may be able to discover an octaploid $(8n)$ individual.

"Our balanced series now stands $1n$, $2n$, $3n$, $4n$, and in general a corresponding increase in size from the $1n$ to the $4n$ condition can be observed in external parts such as leaf and flowers, as well as in their component cells. Such a quantitative change is to be expected from the increased number of chromosomes when the balance is not disturbed by an increase or decrease in individual chromosomal sets. Less expected is the qualitative change in shape from the $1n$ to the $4n$ condition. Considering the leaves of $2n$ plants to be normal, $1n$ leaves are distinctly narrower, and $4n$ leaves are broader. Further, the $2n$ capsules are ovate and $4n$ capsules are nearly spherical. Such qualitative differences between balanced types may be due to quantitative differences in the ease of division or of expansion of cells in the different directions or may be due to the factors in certain chromosomes passing critical points sooner than those in others when the balanced chromosomal number is increased or decreased.

"The condition of the pollen has been found to be a diagnostic feature of considerable value in distinguishing the different balanced types, before the formation of capsules. Thus diploids $(2n)$ have relatively good pollen; tetraploids $(4n)$ have pollen only slightly less perfect than diploids, but the individual grains are distinctly larger; haploids have a high percentage of empty grains (around 75 per cent), and the few good grains present are mainly of the same size as those of diploids; triploids have not only a high percentage of empty grains, but the full grains are of various sizes. Modified diploids, triploids, and tetraploids have pollen characters resembling their balanced types, but generally with a higher percentage of empty grains. Pollen counts can not take the place of chromosomal counts, but they are useful in survey work in determining in which group individual plants probably belong."

UNBALANCED TYPES OF DATURA MUTANTS.

"A paper is nearly ready for publication on trisomic inheritance of the color factor in the $(2n+1)$ mutant *Poinsettia,* which will embody color records on between 12,000 and 15,000 descendants of *Poinsettia* parents. The completed mass of data fully substantiates the idea of random assortment of chromosomes in the purple-white chromosomal set at the reduction division. This is true when the purple and the white factors come from closely similar lines (obtained from Washington, D.C.). When the white factor, however, is derived from a distinctly different line (obtained from Germany), an excess of whites regularly appears in the offspring from certain crosses. The matter is receiving further experimental investigation.

"The trisomic inheritance in the cocklebur mutant is similar to the more typical behavior in *Poinsettia,* except that recessive *inermis* plants appear where they would not be expected. A similar peculiarity in the inheritance of the same factors occurs in tetraploid races and indicates that there is some peculiar behavior of the armed-*inermis* set which is not evident in the purple-white set.

"It is obvious that if there are 12 sets of chromosomes there should be expected 12 mutants of the type $(2n+1)$. These we have called the twelve apostles. At the present time we have, however, at least 20 distinct mutants which, both from their breeding behavior and from counts of their chromosomes, are known to be of the $(2n+1)$ type. In certain cases we have been able to show that one of these mutants is a variety or "acolyte" of one of the apostles. The matter is under investigation, but a provisional hypothesis for which there is some evidence is that the difference between apostle and acolyte is due to a Mendelian factor which produces a visible effect only when certain of the chromosomes are in trisomes.

"Apparently a new type of mutation has occurred in this year's plantings, namely, a somatic mutation producing a sectorial chimera with one branch distinctly abnormal in appearance and the rest of the plant apparently normal. Pollen from the abnormal sector contains a high proportion of bad grains, and chromosomal counts in pollen mother-cells show the tissue to have the constitution $(2n-1)$. This fact suggests that some of the not infrequent bud mutations found elsewhere in plants, such as in the citrus group, may be due to somatic changes in chromosomal number.

"It has been established, that of the modified tetraploids, selfed $(4n+1)$ Globe plants produce over 50 per cent Globe offspring; that selfed $(4n+2)$ Globes produce around 90 per cent Globes; that pollen from a $(4n+1)$ Globe when used on a $4n$ female produces about 15 per cent Globe offspring, while pollen from a $(4n+2)$ Globe used on a $4n$ female produces about 70 per cent Globes.

"Non-disjunctional mutations occur much more frequently in tetraploids than in diploids, and in addition to simple $(4n+1)$ and $(4n+2)$ mutants, double, triple, and quadruple mutants have been discovered. Due to the comparatively slight unbalance produced by the change of a single chromosome in tetraploids, the types are not so readily identified by mere inspection.

In order to obtain an idea of the distribution of chromosomal types in the offspring of $4n$ and of $(4n+1)$ and $(4n+2)$ forms, a cytological study is being made of certain pedigrees from such parents by Dr. Belling, whose report is given on page 99 It may be said, however, that the type of disjunction for normal tetraploids with 48 chromosomes has been established and found to be distinctly different from that for certain 48 chromosome forms which, both from the somatic appearance, with ovate instead of spherical capsules, and from the breeding behavior, had been believed to be of the type $(4n+1-1)$ with a chromosome deficiency in one set numerically compensated by an excess in another. The study shows that of two plants, each with 48 chromosomes, one may be a true $4n$ tetraploid, while the other may be a modified tetraploid with two sets differently affected."

A summary may be given of the chromosomal types already identified. In most cases their chromosomal counts have been determined by Dr. Belling, though in a few instances they have been recognized by morphological appearance and breeding behavior. In the 4 balanced types ($1n$, $2n$, $3n$, $4n$) the 4 forms theoretically possible have been identified. In each of the unbalanced types with one set affected, 12 forms are theoretically possible, and we have identified the following: $(2n+1)$, $(2n-1)$, $(2n+2)$, $(3n+1)$, $(3n-1)$, $(4n+1)$, $(4n-1)$, $(4n+2)$, $(4n+3)$. Of each of the unbalanced types with 2 sets similarly affected, 66 forms are theoretically possible, and we have identified the following: $(2n+1+1)$, $(4n+1+1)$, $(4n-1-1)$. In each of the unbalanced types with 3 sets similarly affected, 220 forms are theoretically possible, but we have identified only one form of the type $(2n+1+1+1)$. In addition, we have identified a form of the type $(4n+1-1)$ of which there are 132 forms theoretically possible, and one form of the type $(4n+1+1-1-1)$ of which there are 2,970 forms theoretically possible. In the above summary only "apostles" are considered. If the "acolytes" were included, the number of possible forms would be greatly increased. It is obvious that an enormous number of forms are theoretically possible by aberrations in chromosome number. Only the even-balanced types can be expected to breed true, but the other types could be propagated vegetatively if they were of sufficient economic importance.

"An effort has been made to induce mutations in the jimson weeds by various external stimuli. Of the $(2n+1)$ mutants derived from capsules which had been subjected to radium rays by Dr. Gager, one (a microcarpic plant) produced when selfed an offspring with about one-fourth of the individuals albinos, which died as seedlings. The inheritance of this albino character is being investigated. Its origin is possibly due to the radium treatment. Cold is a stimulus which has a very marked effect upon the formation of at least the male gametophytes. By its use we have been able to induce non-reduction and disturbances in chromosome disjunction, as indicated by the production of a large number of giant pollen-grains, an increase in the percentage of bad grains, and a wide variation in the size of good grains, and finally the entire abortion of the pollen. The seeds obtained by selfing plants thus treated with cold have given rise, among other mutant types, to 5 haploid and 2 tetraploid seedlings, but, in the majority of the cases at least, apparently the rough and poorly controlled treatment did not happen to reach the female gametes at the critical stage, and it is the female rather than the male gametes which are effective in initiating mutations. We believe that with more accurately regulated cold-temperature rooms it would be possible to control the production of mutants by means of cold treatment."

GAMETOPHYTIC SELECTION IN DATURA.

The investigations of Dr. John T. Buchholz, who has been associated with Dr. Blakeslee, have been carried on at Cold Spring Harbor during the summers of 1921 and 1922. In regard to the selection between male gametophytes, he reports as follows:

"In the Globe mutant the pollen-tubes with $(n+1)$ chromosomes are slower in their growth than the pollen-tubes with (n) chromosomes. This is shown by the fact that the pollen-tubes are grouped in a bimodal curve of distribution when Globe pollen is applied to the stigma, while normal pollen under comparable conditions forms essentially a unimodal curve of distribution. The fact that the pollen transmits the Globe character-complex to only a slight degree when pollen from Globe plants is placed on normal plants is therefore explained on the basis of differential pollen-tube growth."

Dr. Buchholz is also working on a selection of ovules within the ovary and seed capsule—"interovular selection."

THE CYTOLOGY OF DATURA MUTANTS.

As his share of the joint cooperative work on Daturas under Dr. Blakeslee, Dr. John Belling has paid particular attention to the tetraploids. He reports as follows:

"*Normal tetraploids.*—In the late prophase and early first metaphase in the pollen mother-cells, the 48 chromosomes of a normal tetraploid *Datura* are usually connected in groups of four (quadrivalents). At the anaphase these separate 2 and 2, or 1 and 3 (non-disjunction). Examination of the distribution at the second metaphases shows that a division into 24 and 24 has occurred in from three-quarters to two-thirds of the pollen-mother-cells, while the others mostly show 23 and 25, and rarely 22 and 26, etc.

"Normal tetraploids with 12 sets of 4 homologous chromosomes each, should, if the chromosomes in the megaspores are distributed as in the pollen-mother-cells, and if any of the 23 or 25 chromosome pollen functions, give some progeny with 49 and some with 47 chromosomes (and more rarely plants with 46 or with 50 chromosomes). This is the case."

"*Abnormal tetraploids.*—The occurrence of double opposed non-disjunction would lead to the production of gametes with 24 chromosomes, having only 1 of one set and 3 of another. Crossed by a normal 24-chromosome gamete, the resulting plant would have 48 chromosomes, including 3 of one set and 5 of another. Such plants might show over 50 per cent of apparent non-disjunction, and might give up to a quarter of 47-chromosome or of 49-chromosome plants among their progeny, and up to one-sixteenth of 46-chromosome or 50-chromosome plants. Two plants with this large amount of non-disjunction have been specially studied.

"*Tetrads of normal tetraploids.*—Normal tetraploids have rarely shown cases of non-reduction (leading to the formation of 48-chromosome pollen-grains). Two pairs of giant cells have, however, been met with among nearly 3,000 tetrads. Such pollen-grains, if functional, would produce hexaploid ($6n$) plants.

"*Progeny of tetraploid pollinated by normal.*—This difficult cross has resulted in 27 plants, of which 25 have had sufficient chromosome sets counted, and 2 are still somewhat uncertain. 14 were diploid and 2 had $13+12$ chromosomes. The origin of these is uncertain. Six plants of this cross were triploid; one had 35 and another 37 chromosomes. Judging from this evidence as to the chromosomes in the egg-cells of the tetraploids, we have presumably 1 egg-cell with 23, 1 with 25, and 6 with 24 chromosomes. This is the same proportion as was found in the distribution in the pollen-mother cells, namely, three cells giving 24 and 24 to one cell giving 23 and 25.

"*Chromosomes of triploid Daturas.*—The results from crosses with tetraploid pollen add to the evidence as to the assortment in the megaspores. Combined with the previous results from triploid pollinated by diploid, we now have indirect proof as to the existence in triploid Daturas of egg-cells with 12, 13, 14, 15 . . . . 22, 23, and 24 chromosomes.

"*Non-disjunction in diploid Daturas.*—A special examination of 500 second metaphases of normal diploid Daturas by Miss A. D. Bergner resulted in the finding of one (complex) case of non-disjunction (11 and 13). This rare non-disjunction is presumably the basis for the rare formation of $(2n+1)$ mutants.

"*Pollen-mother cells of haploid Daturas.*—The pollen mother-cells of the haploid being taken as 1 in volume (measured between the first and second metaphases inclusive), those of the diploids are nearly 2, the triploids nearly 3, and the tetraploids nearly 4.

"*Evolutionary significance of tetraploidy.*—If any natural species have lately sprung from tetraploids, they should, if their chromosomes differ in size, show 4 of each size instead of 2. They will then show 2 of each size in the haploid state. In studies of species for this purpose plants which show clear chromosomes may be classified as follows: (1) marked size differences; (2) size differences, no haploid pairs; (3) size differences, some haploid pairs; (4) size differences, all in haploid pairs."

COMPARATIVE STUDY OF THE CHROMOSOME GROUPS IN DIPTERA.

After it became clear through the work of Morgan, Sturtevant, Bridges, and Muller that characters of the adult *Drosophila melanogaster* are largely determined by genes which appear to have a definite locus in the chromosomes, it was a natural inquiry whether related species had a related construction of the germ-plasm. Since the problem of evolution of organisms has shifted from that of the soma of organisms to that of their chromosomes, inasmuch as mutations occur primarily in the chromosomes, it becomes important to know about the genetic constitution of the germ-plasm of related species.

This is the problem with which Dr. C. W. Metz is engaged, with the assistance of Miss Mildred S. Moses, Miss Ruth Ferry, and, temporarily, of Mr. S. K. Emerson. The work involves the genetic behavior of mutants. It is slow and laborious, but significant advances have been made.

Breeding Work.

In *Drosophila willistoni* the results of the study of 28 sex-linked mutant characters have been published during the year:

[These serve as a basis for] "beginning the detailed comparison of the genetic constitution of this species with that of the other species under observation. The recent discovery by Miss Ferry of additional mutant characters that appear to parallel those of other species provides the type of material needed for this comparison. The genetic relations of these characters have not yet been fully analyzed, but the available data suggested a more definite relation to conditions found in other species than was intimated in last year's report.

"In *Drosophila virilis*, whose study has likewise been continued during the present year, 44 mutant characters are now known, of which 11 are dominant characters. Present evidence indicates that 6 groups of linked characters have now been identified in this species, corresponding to its six pairs of chromosomes. The "chromosome map lengths" of these groups, based upon percentages of crossing over, range from approximately 110 units in the case of the X-chromosome to zero in the case of one group of three non-sex-linked characters. It is possible that the latter group represents the small, dot-like pair of chromosomes, although the evidence is not yet clear, partly because of the fact that the sixth group has not yet been tested for crossing over.

"Evidence from the sex-linked characters in *Drosophila virilis* tends more and more to indicate a genetic as well as morphological correspondence between the X-chromosomes of this species and those of *Drosophila melanogaster*. The non-sex-linked characters have not appeared in sufficient numbers to make possible a comparison of the non-sex-linked groups.

"With the accumulation of mutant types for comparison, both in these species and in species studied by other workers, significant results are obtained more and more rapidly. Furthermore, the element of speculation, which loomed large when the study of *Drosophila virilis* was first undertaken, has now been dispelled to a great extent by the appearance of parallel characters in this and other species. Such characters agree in different species to such an extent as to make the probability of homology very great; and this in turn allows a comparison of the genetic make-up of chromosomes in different species to be made with some assurance.

"If the present evidence is reliable, even in part, it indicates a considerable degree of stability in chromosomal organization over relatively long periods of time during the evolution of the species involved."

Work on *Leria pectinata*, on which a beginning was made by Dr. E. G. Anderson (Year Book, 1921, p. 112), has progressed in spite of various interruptions.

Dr. Anderson has also carried out the experimental study of crossing over in triploid flies, as a first step in which it has been necessary to make to order all of the flies to be used in the experiments. Each of the initial stocks to be used contains four or more mutant characters. The required compound stocks have been synthesized.

Cytological Work.

It is believed that progress will be most rapid when the cytological and the genetic methods of attack on the problem of chromosome organization and behavior are combined. The studies on spermatogenesis and oogenesis in various Diptera have been continued by Dr. Metz. Attention has been devoted especially to the exceptional conditions found in one of the robber flies, *Lasiopogon bivittatus* Lw., specimens of which were taken and prepared in Wyoming. In these specimens the spermatocyte nuclei at certain stages exhibit such peculiar relations between nuclear wall and chromosomes as to suggest that the latter are surrounded by thick, transparent envelopes of a gelatinous nature, which serve, among other things, to hold the chromosomes away from one another and from the nuclear wall.

The study of what appears to be incomplete synapsis of certain chromosomes during spermatogenesis in *Dasyllis*, reported previously, has been completed by Dr. Metz, together with a partial study of oogenesis in the same forms.

An examination of tetraploid somatic cells in *Sarcophaga* has indicated that in prophases of these cells all four homologous chromosomes of each sort come into intimate and equivalent association, just as do the two homologues in diploid cells.

In addition to the above, the comparative survey of chromosomal conditions in the Diptera has been continued, particularly by Miss M. S. Moses.

EXPERIMENTAL MODIFICATION OF THE GERM-PLASM.

Genetic Behavior of X-rayed Mice.

In the Year Book for 1921 reference was made to the experiments of Drs. C. C. Little and H. J. Bagg, in exposing mice to very small doses of X-rays. The dosage given was one-fifth of an erythemal dose for five successive days. The radiation was given over the whole body to both male and female parents. This part of the experiment was performed at the Memorial Hospital in New York City.

The further experiment involved the contrasting of the breeding behavior of these mice with that of untreated controls. Dr. Little reports:

"The first litters of young to be recorded from any of the treated animals did not appear until at least six weeks after radiation. As a general thing, these litters were slightly smaller than the normal litter size, although the young produced were apparently normal and healthy. These animals and their descendants have since been bred *inter se* with brother-to-sister matings. More then 4,500 mice have been recorded in these experiments. Approximately 1,000 of these are descendants of the untreated controls. Among these have appeared two grossly abnormal individuals, both in a single, unusually large litter. Experiments are now being conducted to determine whether or not this tendency to produce abnormals is hereditary, and if so, what the type of inheritance is. Information on this point should be obtainable within the next year. Among the descendants of the X-ray pairs, more than 275 grossly abnormal individuals have been obtained. It has been possible to group these abnormalities somewhat as follows:

"(1) *Eye lesions.*—These are usually hemorrhagic, involving a dry or crusted appearance of one or both eyes. This abnormality is clearly visible at birth and persists throughout the lifetime of the individual, usually producing blindness due to clouding atrophy, and in rare cases apparently complete absence of the eye. The inheritance of this abnormality has been carefully studied, and it has been found to be Mendelian in its behavior and recessive in nature. The recessives, when bred together, do occasionally give individuals somatically normal in appearnace, but these are merely somatic "overlaps" and breed as abnormals. Since the type of lesion appearing in this abnormality usually involves hemorrhagic areas, the symbol h has been given to this mutation, with H as its normal allelomorph.

"(2) *Abnormal head.*—This abnormality involves a series of different types. The commonest of these shows defects in, or absence of, the lower jaw. Correlated with these appears reduction or absence of the mouth opening and of the tongue. Occasionally, due to the reduction of the lower jaw, the tongue appears large and protruded from the mouth. Naturally these mice are either born dead or die soon after birth, since it is impossible for them to nurse, and in some cases to breathe. At other times the eyes are also involved, but in these cases there is no lesion to the outside, as in the types described under heading (1). The eyes are either merely reduced or perhaps more commonly completely absent. This condition may or may not be accompanied by abnormalities of the mouth and jaw already referred to. When the mouth is normal and one or both eyes abnormal, the mice may live for 5 or 6 weeks. Such individuals are, however, always undersized, highly nervous, and weak. None of them has attained breeding age. The effect of this modification is, then, always lethal, although the lethal action may be in some cases delayed for a considerable period.

"(3) *Foot and leg abnormalities.*—These involve a reduction of digits, syndactylism, and other abnormalities of any or all of the feet and legs. This abnormality in all probability bears some relation to the eye-lesion abnormality, although the genetics have not been clearly worked out as yet.

"(4) *Hair abnormality.*—This involves a shortening of the hair on one or both flanks. In pigmented mice this produces a lighter degree of pigmentation in the regions where the hair is shorter, thus producing a "saddle" effect. This abnormality has not yet been worked out in relation to those already described, but it is clearly distinct and is extremely striking in appearance. Its identity as a structural character has been determined by its appearance on an albino.

"(5) *Lesions involving the entire cranium.*—These occurred in the same family as that giving the first described type of hemorrhagic eye abnormality in some 8 or 9 mice which were born dead with partial or total absence of the cranium. These acraniate forms are very striking and are unlike any other abnormalities hitherto described in mice.

"(6) *Minor abnormalities of the eye involving breaks in the ring of iris pigment to greater or lesser extent.* These have occurred in only a few cases and, as it happens, the mice have not survived.

"(7) *Spinal lesion.*—This has occurred in one animal, resulting in death a short time after birth. The lesion was in the sacral region, and superficially resembled spina bifida."

In order to determine whether or not there is a direct effect of X-rays upon the treated animals themselves, Miss Margaret Schneider and Mr. L. H. Snyder are sectioning a series of eyes and gonads of animals which received the same dose as did those used in the original X-ray experiment.

MODIFIABILITY OF THE GERM-PLASM BY ALCOHOL.

This experiment, which has been continued for 6 or 7 years, may now be considered practically completed. Though with the use of rats no such striking results were obtained as reported by Stockard for guinea-pigs, nevertheless a clear effect of alcohol in reducing the capacity for learning in the treated generation was found; and this effect persisted to the next generation, even if that generation was not subjected to further alcohol.

It remained to learn if there were any slight morphological effects of the alcohols, and, if so, any persistence of those effects to the next generation. To this end the skull and the bones of the appendages were saved for measurement. By an accident many rat skulls of the parental and first filial generations were destroyed. However, 472 skulls altogether have been measured in four dimensions: total length, width, height, and length of nasal bones.

When this total is subdivided according to the generation and sex, the numbers are too small to afford a basis for any conclusion as to the relative size of tests and controls. The work was done under Dr. MacDowell's direction by the Misses Vicari and Hubbard.

THE SIGNIFICANCE AND CONTROL OF SEX.

Relation of Reproductive Overwork and Storage Metabolism of Ova to Sex.

During the year Dr. Oscar Riddle has obtained new light upon the mechanism of "reproductive overwork" (Whitman, Riddle) by the observation that the suprarenal glands of female pigeons undergo marked and prolonged hypertrophy in very exact coincidence with each ovulation period (dehiscence of two ova); and by the further observation that the carbohydrate metabolism of the bird undergoes a simultaneous change, as shown by an increased concentration of the sugar of the blood. The data for the latter point were obtained by Dr. Riddle with the cooperation of Dr. H. E. Honeywell, of the Department of Physiology, Columbia University. Both of these results are represented in curves, figure 1, which shows, in addition, that the oviduct begins a pronounced temporary enlargement, and one or two ova begin a period of extremely rapid growth, both coincident with the beginning of hypertrophy in the suprarenals.

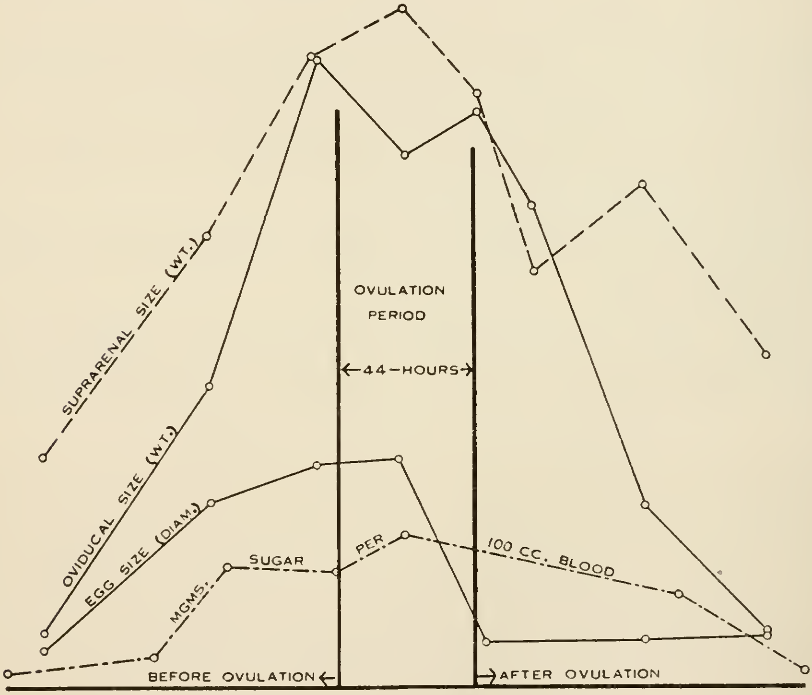

Fig. 1.—Variation of weight of suprarenal gland, weight of oviduct, diameter of egg, and proportion of sugar in the blood, before, during, and after ovulation.

The data of the curve represent their first series of determinations only; and, although later determinations have not given uniformly smooth results, it is believed that the situation expressed by the curve has been satisfactorily demonstrated. The curves for suprarenal size, oviducal weight, and diameter of ovum were constructed from data obtained from 22 common pigeons; the curve for blood sugar from repeated determinations on 5 healthy ring-doves. Essentially similar curves have been obtained for two additional groups of birds. Though only one of the expected effects of suprarenal hypertrophy has been investigated, the result clearly indicates that "the enforcement in pigeons of frequent and continuous ovulations throughout the year, as this has been practiced and reported by Whitman and by Riddle, with important results on sex, viability, and longevity of offspring, is doubtless accompanied by an increased and nearly continuous mobilization of carbohydrate in the female parents."

A study of the effects of some of the products of the endocrine glands upon the storage metabolism of ova has yielded some definite results which clarify and confirm Dr. Riddle's earlier interpretation of this matter. Among these glandular products are some which are well known to have marked effects upon the basal metabolism of the organism. Of these glands the thyroid has the most pronounced effect in increasing the metabolism. Dr. Riddle has demonstrated that the oral administration of thyroid, in quantities so small as to be compatible with continued reproduction by normal healthy females, distinctly *diminishes* the storage metabolism of the ova being produced. It would seem necessary to conclude that this reduced storage (smaller yolk size) is a reflection of the *increased* oxidation which is known to characterize the action of this substance on the body as a whole. From the beginning of Dr. Riddle's studies in 1911 he has been led by other kinds of evidence to interpret high storage values of the yolk to mean low oxidizing capacity. Still further confirmation of this interpretation has been obtained from similar studies with the products of other glands of internal secretion. The whole of these data will be summarized at an early date and form a chapter of a volume now in preparation. A summary of the data obtained during one year from a single thyroid-fed female is given in table 1.

TABLE 1.—*Effects of desiccated thyroid (20 mg. daily) on the storage metabolism of the ova (yolk weight) of a single ring-dove during one year; 6 control eggs alternating with 6 treated eggs.*

Means for periods of dosage and control.	No. of eggs.	Average weight (grams).	
		Eggs.	Yolks.
Mean for control.........	30	9.508±0.043	1.940±0.021
Mean for thyroid dosage..	18	9.928±0.064	1.767±0.020

Dr. Riddle earlier reported that one unique bit of evidence for the correlation of large yolk-size of the egg with femaleness in the embryo which arises from it has been obtained from measurements of twin-producing eggs. The important fact was that all of the few female single-yolk twins obtained in this research were associated with yolks demonstrably of extremely large size. On the basis of his illuminating experiments on twinning and double monsters in fish embryos, Stockard has recently suggested that twins in birds probably arise in those particular eggs which are laid prematurely. If such eggs are laid a few hours earlier than is normal, the process of gastrulation in the embryo would have to occur at the prevailing lower temperature of the air. On Stockard's view a lowering of the temperature during the sensitive period of gastrulation induces double gastrulation and resultant twins.

In making a test of the above hypothesis, Dr. Riddle obtained a relatively large series of eggs of varying stages of prematurity and subjected them to various temperatures during variable periods. His results strongly indicate that twins and double monsters are not thus produced in pigeons. From 200 adequate tests there resulted 192 normal embryos, 5 with some abnormality probable, 3 possibly though not probably of double nature, and none plainly twins or double monsters. When these data are reviewed in the light of other limiting circumstances previously reported, the result is, it is believed, a conclusive demonstration that the particular twins on which our studies are based were not the result of premature laying with consequent modification of the gastrulation process. The evidence which our cases of twins afford for the relation of high yolk storage to femaleness remains, therefore, quite unimpaired.

Control of the Sex-Ratio.

Attention has been called in earlier Year Books to the attempts made by Dr. A. M. Banta to control the sex-ratio in Cladocera. In certain lines in this group males have never been observed; in others, males occasionally appear. The conditions that determine their appearance have never been discovered. With the collaboration of Mr. L. A. Brown, of the University of Pittsburgh, important progress has been made during the past year, first, in determining the critical period during which the sex of the offspring of *Moina macrocopa* is subject to experimental control; second, in the elimination of a number of environmental factors as primary agents in sex control; third, in securing, by experiment, suggestions as to the specific environmental factors involved.

To find the stage in the developing egg at which sex is determined, 32 experiments were made (involving a record of 6,895 young) in which females were removed from the crowded bottles at various instars. No males appear among the young of mothers relieved from crowding prior to the late third instar. But if the transfer was delayed until the beginning of the fourth instar (when the eggs are in the brood pouch) the normal proportion of male offspring appeared. It is concluded, accordingly, that in this species sex is determined immediately before the eggs leave the ovary; and this is known, in some species of Cladocera, to be the time of maturation of the parthenogenetic egg.

As for the second and third points, it was known from our earlier experiments that in 95 per cent of the cases males were produced in bottles containing 10 or more mothers, if the bottles were left undisturbed, while bottles containing only 1 mother never yielded a first brood of male young.

Two groups of experiments were conducted. In the first group aeration of the culture water was accomplished (1) by bubbling air through the test bottles, (2) by bubbling oxygen through the bottles, (3) by shaking the bottles with air, and (4) by shaking the bottles with oxygen. Thirty experiments of this type gave 4,364 control young, of which 38.7 per cent were males, while in the tests there were 3,870 young, of which 24.9 per cent were males. Thus the aeration apparently reduced the percentage of males by one-third.

In the second group the mothers themselves were treated by aerating them on a slide in a thin film of water. Of 2,122 young of the controls, 55.9 per cent were males, and of 2,706 young of the tests only 19.5 per cent were males. Thus the treatment of the mothers apparently reduced the number of their male young by nearly two-thirds.

Experiments were planned to test whether or not this result was due to the reduction of carbon dioxide. Uncrowded mothers were treated with carbon dioxide. If the crowding effect was due to carbon dioxide, this treatment should give males. Twenty-one experiments were attempted in which the amount of carbon dioxide given ranged from 20 bubbles to a lethal dose. All of the 3,285 young produced were female. Hence it would seem that male production is not determined by an excess of carbon dioxide in the culture water.

The next expedient tried was the removal of oxygen from the uncrowded bottles by streaming nitrogen through the culture water. The 3,969 young resulting, except for a few chance cases, were females.

Six experiments have been completed, in which nitrogen was bubbled into crowded bottles. These experiments included 206 mothers and 1,240 young. The crowded controls, as usual, gave many males (40.9 per cent), and the treated bottles gave 27.3 per cent males, a difference of one-third.

From the foregoing brief summaries of Dr. Banta's experiments it will be seen that, while aeration decreases the percentage of males in crowded bottles, an increase in carbon dioxide or a decrease in the amount of oxygen in uncrowded bottles fails to cause the production of males. It will also be noticed that nitrogen apparently produces somewhat the same result when bubbled through a crowded bottle as is accomplished by the aeration.

Control of Production of Sexual Eggs.

Associated with the problem of control of the sex ratio in *Daphnia* is that of the experimental control of the production of that peculiar type of egg which will not develop unless fertilized, called ephippial egg. This control has been secured, in Dr. Banta's experiments, with two of the laboratory forms and partial control has been secured for a third form.

"With one of the (?) *Daphnia pulex* types, the '984 type,' the simple expedient of crowding the young from birth until they are sexually mature determines the production (*not* of males as in all other forms similarly treated but) of 'ephippia' bearing the sexual eggs. With *Moina macrocopa* ephippial eggs are produced by females crowded in strained spring water from soon after birth until sexual maturity. This species may also usually be caused to produce ephippial eggs by crowding the young females in old, somewhat depleted food. It would seem that paucity of food and the accumulation of waste products may possibly both be involved in this control measure.

"*Daphnia longispina* is likewise somewhat amenable to the last-mentioned treatment as a means of ephippial production.

"The '984 type' has not been known to produce males, although it has a long laboratory history and has been designedly subjected to rather varied conditions at different times. It is believed that males do not occur in this form. Of further interest is the anomalous discovery that in this form '*sexual*' eggs develop *asexually*.

"To the previous evidence bearing on the non-occurrence of the supposed internal sexual cycle, (1) the long-continued parthenogenetic reproduction, (2) the undiminished vigor under continued parthenogenesis, and (3) the fact that the sexual phenomena have been experimentally controlled, may now be added a new line of experimental evidence.

"Were there an internal sexual cycle one should expect Cladocera, because of the working of the internal factor, to become more and more prone to manifest sexuality as parthenogenesis continues. Experiments in control of male production, using females from stock long subjected to parthenogenesis in comparison with females just hatched from sexual eggs or having descended by parthenogenesis for only one to seven generations, showed that the stock which had recently gone through sexual reproduction produced males just as freely as stock which had been exclusively parthenogenetic for 300 generations."

Selection of Sex Intergrades in Daphnia.

Continuing the experiments reported last year, Dr. Banta has, with the assistance of Mr. George G. Snider, obtained from the selection of the sex-intergrade stock of *Daphnia longispina* a mass of data which indicate that the degree of sex-intergradeness is clearly inherited, that its inheritance is dependent upon a single mutable factor (or several factors), and that genetic change is rather frequent, though not equally frequent in all strains of this stock.

Sex in the Mucor Cunninghamella.

The study of the sexual condition in the mucor genus *Cunninghamella* has been brought to completion by Dr. Blakeslee. The results of making contrast tests between more than 200 races from 4 different species offer no evidence for an exception to the rule of a strict sexual dimorphism in this genus. Similar studies on the intraspecific sexual reactions in some 30 different species of other genera as well as study of the intraspecific reactions between the sexual races of these different species strongly indicate that there is a common fundamental something peculiar to each of the two sexes throughout the whole group of the mucors.

INHERITANCE OF SPECIAL TRAITS.

Flowering Plants.

The physico-chemical properties of the leaf-tissue fluids of Egyptian and Upland cotton and of their hybrids.—Genetic work has been largely confined in the past to the visible morphological characteristics of organisms, such as form and color. The possibility of studying the genetics of certain of the biophysical and biochemical peculiarities has been opened up by the demonstration that Egyptian and Upland cottons, which hybridize freely, differ in certain of these characteristics, such as osmotic concentration, specific electrical conductivity, and hydrogen-ion concentration in their leaf-tissue fluids.

This demonstration was made by Dr. J. A. Harris in studies carried out by courtesy of the U. S. Department of Agriculture at the Cooperative Testing Station on the Gila River Indian Reservation at Sacaton, Arizona, in 1920 and 1921. An investigation of the sap properties of the F_1 hybrid between Egyptian and Upland cotton, carried out simultaneously with the above investigations of the differentiation of the two forms, shows that the leaf-tissue fluids of the hybrids are characterized by a lower osmotic concentration and a lower specific electrical conductivity than are those of either of the parent forms. The ratios of specific electrical conductivity to freezing-point depression indicate that the hybrid absorbs relatively larger quantities of electrolytes than either of the parent forms. The tissue fluids of the hybrid are characterized by a lower acidity than are those of the Egyptian parent, but by a higher acidity than those of the Upland parent. With respect to this sap property, the heterozygous individual is, therefore, intermediate between the two parent forms.

A detailed discussion of the foregoing results is nearly ready for publication.

These investigations have been continued during the present year, by a more detailed comparison between the Egyptian and Upland types, involving several newly imported Egyptian varieties. The F_2 generation of hybrids has also been investigated. These studies occupied the attention of Dr. Harris, with the cooperation of Messrs. Arnold H. Johnson, Robert D. Evans, and A. T. Valentine, during several weeks of the summer.

Mirabilis.—Dr. John Belling has been working on the "multimutating" genes of the four o'clocks, testing the hypothesis that the genes in the chromosomes have a number of possible allelomorphs to any of which they may eventually mutate.

"In the homozygous tricolor *Mirabilis* two pairs of multimutating genes are found. The mutations are from yellow-striped to yellow, and from red-striped to red, but the red shows only in presence of the gene for yellow. The numbers of mutant progeny from tricolor parents were 6 per cent of the yellow and 4 per cent of the red in 458 offspring. Totaling all cases in which one of a pair of genes for yellow striping could mutate to a gene for yellow there were 4 per cent of mutants out of 820 progeny; and in the similar cases of red striping, 5 per cent of mutants in 1,063 progeny. In the parents of one sibship, the gene for yellow striping was heterozygous, and in its progeny there were 3 per cent of mutants out of 112 plants, where only about half as many are expected as from a homoygous parent. A distinct mutant (probably chromosomal) has been found in tricolor progeny, of which the homozygous condition seems lethal, and the heterozygotes occur in less than half the normal number, 109 seeds giving a quarter of normals and less than a quarter of heterozygotes, with only one recognizable mutant homogote."

Genetic Basis of Animal Behavior.

Heredity of behavior in dogs.—Considerable time was devoted during the year under review to getting a quantitative expression of the behavior of dogs as a preliminary to a study of the genetic elements in such behavior. The work met with wholly unanticipated difficulties. These are described by the experimenter (Dr. E. C. MacDowell) as follows:

"(*a*) *Discrimination apparatus.*—The difference in the adaptability of two litters of dachshunds in the preliminary training in the discrimination apparatus was noted in the Year Book of 1921, pages 129–130. The training of these two litters was continued for 6 months. For the first 3 months the buzzers were used as signals; for the last 3 months the lights were the signals. With the buzzers, there seemed to be a fair degree of learning shown by each set, so that on the last 7 days of the training with the sound signals, no dog made less than 8 correct trials out of the 10 per day. The difference between the two litters in the preliminary training did not appear in their ability to form sound associations. In the training with the light signals there are more records in the last 7 days above 50 per cent correct per day than of 50 per cent and under; this indicates a somewhat stronger tendency to go towards than away from the light, but none of the dogs has approached formation of full association of the light with food. The two litters gave, in general, like results in the training with light signals.

"During the training with the light signals, certain positive habits were developed that very seriously interfered with the progress and analysis of the behavior. In spite of special training to eliminate these habits the subsequent behavior was complicated by the probable continued effect of these habits in varying degrees.

"Another litter of five 6-month dachshunds was started at the first of the year and trained in this apparatus for 3 months with the buzzer signals. At the end of this time there was no indication that any association had been formed; the number of correct trials per day fluctuated around 5 out of 10. In only one case a record of 9 correct was made; in another case (a different dog) a record of 10 correct. The subsequent behavior indicated clearly that these cases were due to other causes than the formation of an association between the buzzer and the food. The preliminary training was as similar as possible to that given to the three litters which learned the association with the buzzer; moreover, the failure of this litter to learn can not be ascribed to any family difference, since the parents of this litter were from the same strain as the successful litters.

"A group of 4 chow-chow bitches was given the preliminary training in this apparatus. In spite of great differences in their ages and experiences they all failed to master the necessary preliminary routine of the apparatus; even after three months of training.

"Since this apparatus was planned to test the relative ability of different breeds to form associations with a series of different types of signals, and since no indications have been found of any association with strong light signals, and, further, since three months is not a long enough time to form the sound associations in a litter from the stock that had previously given three litters that did learn them, and since the chow-chows tested were not amenable to the necessary preliminary training, it becomes clear that this apparatus provides an unsatisfactory method of testing native tendencies as the basis for genetic studies.

"*Jumping test.*—In searching for suitable tests for measuring family and racial characteristics in dogs, an apparatus was constructed to find the height from which a dog would jump. It was an elevator consisting of a closed box operated by block and pulley, running up and down on tracks that reached up to a height of 20 feet. The test was started with the height 2 feet; in practically all cases the dog jumped immediately when the door was raised; so no preliminary training was necessary. After jumping, the dog was returned to the house, and the next one in the litter was tested at the same height. In this manner all the dogs in a litter were put into the elevator at successive heights of 2, 3, 4, 5, etc., feet, until the limit was reached. No special reward was given to stimulate the jumping, since up to a certain height all the dachshunds were anxious to jump down. The test for a dog was concluded for the day when he sat for 20 minutes without jumping. The test was repeated every two months. The records gave the height jumped, the time between the opening of the door and the arrival in the straw bed, and the vocal behavior of the dog. Three litters of dachshunds and four chow-chow bitches were tested by this method.

"Certain general results were found. There is a strong tendency for a dog to take longer before jumping as the height increases; also, at increasing heights the dog begins to whine before jumping, then to cry, then to chatter or bark, and finally to combine all these sounds in a violently excited behavior. As the limit of his jumping is reached the sounds reach a maximum; as the limit is passed the noises diminish in intensity and the dog may lie down at the back of the box. There are many variations from this general behavior and many individual idiosyncrasies in the character of the sounds made.

"Some dogs would jump from the elevator when raised to 12 feet; others would refuse to jump at 4 feet. There was no indication of correlation between such differences and the size of the dogs. The tests gave higher limits when repeated after two months, so, in spite of the brief duration of the test, an element of learning was obviously involved. One litter showed great uniformity in jumping from considerable height; another litter showed great irregularity, some making high jumps while others refused to jump much above the initial 2 feet. These seemed to be favorable indications for the success of the method. It had the great advantage of being brief, it gave direct numerical data, and it required no preliminary training. But when the chows were tried, difficulties were encountered; they preferred to sit in the box rather than use the energy to jump. One of them would jump whenever some extraneous sound or motion attracted her to the ground; the others sat contentedly in the elevator when it was raised above the first positions; two would jump when called or at the sight of a person. Although it is possible to show that the dachshunds jumped from greater heights than the chows under the same given conditions, such a comparison can have little significance, for it was obvious that the dachshunds were anxious to jump, and in most cases would jump till they bounced high on landing in the straw, while the chows would lie quietly till the proper incentive appeared and would then leap at once with the greatest ease.

"Whereas the method at first appeared to offer many advantages and to give a simple measure of temperamental differences, it soon became clear that behind its simple data there were many causes. The very same data could mean very different things. When a dog refused to jump from 4 feet it may have meant (1) that the dog was scared by the height, or (2) that he had no interest in the ground, and remained in the elevator because he was contented to do so. When a dog jumped from 10 feet it may have meant (1) that he had a great desire to run about on the ground, (2) that he was scared by the unusual elevation, or by the elevator itself, or (3) that he had a well-knit body, or a light body, that had not been hurt by the jolt in landing upon the straw in the previous jump. One could be led to believe that the height data measured courage, by observing many of the dachshunds and hearing their noises as the height increased; yet, for the chow, height certainly does not measure courage, and quantitatively it probably measures nothing at all. More likely in this case the data indicate that chows were not stimulated by a situation that did stimulate dachshunds, but such a difference between the breeds applies only roughly, for reversed conditions were found in both breeds. So by the same units we may be measuring one character in some cases while in others we may be measuring a different character or measuring nothing; and comparisons mean nothing if the data do not measure the same thing. Although considerable data have been gathered from these elevator tests, they are now believed to have little value for a comparative study of native temperament in different families or different breeds. The method is too simple for an analysis of a vastly complicated situation."

To the difficulties in obtaining measurements of behavior of the dogs was finally added an epidemic of distemper. In the face of such difficulties it has become clear that the problem of inheritance of the elements of behavior in dogs is too large and too expensive for this Department to undertake with its limited resources. There is required for the work the cooperation of a group of investigators including at least an animal behaviorist and a physiologist in addition to a geneticist.

Heredity of Learning Capacity in Mice.

Miss E. Vicari was a guest of the Department during the summer and continued her investigation into the rate of learning in mice, using for this purpose, in addition to the strains which she reported last year, the abnormal-eyed descendants of X-rayed mice and a closely inbred strain of dilute brown mice.

The Inheritance of Cross-Bill in Pigeons.

This character has appeared at various times in the past in connection with other breeding work. During the past two years several matings have been made by Dr. Riddle in order to test the mode of its inheritance. This has not been determined, but the fact of inheritance is clear. It has also been learned that the character is more properly described as "deformity of the beak region." This manifests itself in various ways—absence of little or much of upper beak or of lower beak, upturned beak, one or both nares unclosed, wide or unusual gape.

The Inheritance of Blood-Sugar Values in Generic Crosses.

Our ample collection of pedigreed birds, particularly of hybrids from crosses involving different genera, has made it possible to obtain a partial test of the behavior in hybridization of such a physiological or chemical character as the concentration of the sugar of the blood. This work was done by Dr. Riddle with the cooperation of Dr. H. E. Honeywell.

When it was learned that the Japanese turtle-dove (*Turtur orientalis*) has a relatively high concentration of blood sugar, while the ring-dove (*Streptopelia alba*) has the lowest amount of blood sugar of any of those measured by us, we naturally selected the F_1 hybrids of these two species for this test. A study of the F_2 hybrids is highly desirable, but this has not yet been made. The individuals used to determine the amount of blood sugar in the parent species were not the parents of the particular hybrids whose blood was examined. All of the hybrids in our collection having this type of origin were included in the study.

The result of this inquiry indicates that 68 of these hybrids have a blood-sugar value almost exactly intermediate to that found for the two parent species. In these F_1 hybrids the data for blood sugar indicate as truly an intermediate value as do the data for size. An additional group of F_1 hybrids has been examined. Other studies in progress should soon make it possible to estimate the significance and value of the results already obtained.

Coat Colors in Dogs.

In connection with the observations on coat color of the dachshunds and chow-chows at this Department, Miss Jane Hubbard, in collaboration with

Miss E. E. Jones, has made an analysis of the records in the Stud Books of the American Kennel Club. The necessary tabulations and calculations have been made and the material is now ready for publication.

Heredity of Blood Types in Mice; a Negative Result.

As is well known, human blood falls into a number of types which differ by the capacity of the serum to agglutinate the corpuscles. Obviously a person's own blood will not agglutinate his corpuscles and thus destroy the functioning of the blood. Also the blood-serum of A's own blood *type* will not agglutinate the corpuscles of A's type. But there are other types which probably will. Von Dungern and Hirschfield abroad and Ottenberg in this country have maintained that these types are inherited simply, and indeed in Mendelian fashion. Others dispute this conclusion. It was thought desirable to test the theory in a rapidly breeding animal whose breeding could be controlled. It was stated that blood groups similar to the human occurred in rabbits and cattle. It was decided to look for them in mice, especially since the numerous collaborators working on mice at this Department during the summer would bring together a great variety of strains. Accordingly, the necessary technique was worked up by Dr. MacDowell in preparation for the testing of the various stocks of mice for isoagglutinins that might appear in regular groups.

From 11 different races of mice contributed by Drs. Little, Dunn, and Strong, Professor Gates, and Miss Vicari, 48 sera were made and a total of 300 samples of cells were tested; the total number of different combinations of cells and sera was 1,180. Of these combinations, 2 showed agglutinations. Repeated tests with sera from the same stock and cells from the same mice failed to substantiate these positive findings.

Since one mouse yields such a small amount of serum, it was thought that some other serum, obtainable in larger quantities, would be far more satisfactory as a test for differences in the bloods of different strains. To this end 4 guinea-pig sera were used in making 180 tests; 4 sheep sera were used in making 136 tests; and 9 rat sera were used in making 275 tests. In every case the guinea-pig and the sheep sera showed unquestionable agglutination, and in no case did the rat serum show any signs of agglutination, although the whole range of stocks was represented in all three cases.

Our attempt to study the heredity of blood groups in mice has thus ended, since there apparently are no blood groups in mice. All we found was that mouse cells are agglutinated by the serum of guinea-pigs and sheep, but not of rats.

Susceptibility to Inoculate Tumors.

The work on inoculable tumors, which was reported on at some length in the Year Book for 1921, pages 122–127, has been continued by Doctors Little and L. C. Strong, and by the use of larger numbers of individuals the Mendelian behavior of the factors underlying susceptibility to the two adeno-carcinomas dbrA and dbrB has been more clearly established.

In the F_2 generation susceptibility to the dbrB tumor depends on the presence of at least two independent Mendelian units, since a typical 9:7 ratio is obtained in this generation. The susceptibility factors are called A^{st} and B^{st}. For the dbrA tumor, 3 Mendelian units are necessary. Of these, 2 are the same as the 2 permitting the growth of the dbrB tumor. The dbrA tumor will continue to grow, however, only when a third factor called C^{st} is also present. Thus, Dr. Strong has shown that the physiological differences between histologically identical tumors are genetic differences.

The work has now reached a point where it will be necessary to conduct a series of individual tests leading to the isolation of lines differing in single mendelizing factors for susceptibility and immunity.

Doctor Strong is continuing his work on these tumors with special reference to their rate of growth and their relation to other spontaneous tumors which have arisen in his stocks, while the experiments dealing with isolation of single-factor lines Doctor Little hopes to carry on at the University of Maine.

Cooperative Breeding of Mice.

The need of a central agency to maintain mutant strains of mice has been felt for some time. The preservation of such strains is a prerequisite to extensive linkage studies. Inasmuch as this Department has come to be the gathering-place of many mouse geneticists during the summer, it has been requested to perform this service. In view of its limited resources and in view of the danger from epidemics, the Department can not guarantee to take care of all mutant strains that may be offered in the future, but it is glad to be of such service as it can in this matter.

At present the following stocks are on hand:

(1) Lathrop Japanese waltzers, which will be bred by brother-to-sister matings.
(2) Inbred dilute browns of Little.
(3) Abnormal and control X-ray lines, including the gene for abnormal eye of line 85 from Little.
(4) Bagg albinos.
(5) Storrs albinos, carrying the pink-eye factor; two wild lines.
(6) Storrs-Little, a race parallel to the dilute browns, in which homozygotes of the different dilute and pink-eye combinations will be sorted out to provide known stocks for testing the genetic constitution of the very confusing pale combinations.
(7) Piebald and black-eyed whites from the inbred race of Strong.
(8) Dilute pink-eyed browns, which, with the introduction of the waltzing character, will become very nearly the ultimate recessive for the more familiar genes, and hence be very valuable for the analysis of individuals of unknown constitution.

GERMINAL AND SOMATIC VARIATIONS.

Mutations in Cladocera.

Cladocera are prevailingly parthenogenetic; hence all individuals of a clone are expected to be alike except as mutations occur. The species bred by us are 13 in number and comprise 71 lines, as follows: *Daphnia longispina*, 3 lines; *D. pulex*, 17 lines; *Simocephalus vetulus*, 5 lines; *S. exspinosus*, 10 lines; *S. serrulatus*, 21 lines; *Simocephalus* sp?, 2 lines; *Ceriodaphnia rigandi*, 1 line; *C. megalops*, 1 line; *C. quadrangula*, 1 line; *Moina rectirostris*, 2 lines; *M. affinis*, 2 lines; *M. macrocopa*, 4 lines; *Lathonura?* 2 lines.

In addition to these 13 clearly distinct species, there are five morphologically different types of *Daphnia pulex* and four different types of *Simocephalus serrulatus*. These types have constant differences and some of them are doubtless entitled to specific rank. The usefulness of this varied stock as observational material and to serve as checks upon various conclusions justifies the relatively small amount of labor involved in its maintenance. In these lines various mutations have arisen. The physiologically different strains of line 757, whose histories are set forth in Carnegie Institution of Washington Publication No. 305, and the sex-intergrade (physiologically and morphologically distinct) strains of *Simocephalus spinosus* and *Daphnia longispina*, have been previously mentioned in these reports.

Two new mutations have arisen during the past year, both involving the head form in *Daphnia longispina*. The first of these mutations is a marked indentation of the front of the head serving to lengthen the anterior margin of the beak and imparting to these "excavate head" animals a somewhat grotesque appearance. The second mutation is a shortening of the posterior beak margin, and while less striking in appearance than the other, nevertheless seems to be a good character. Work is being done on the inheritance of these new characters.

A point of interest with reference to excavated head is the undoubted recurrence of the mutation. Occurring first in September 1921, it reappeared in another strain in the following February, in a third strain in June, and in a fourth strain in August. It is worth noting that the occurrences of this mutation are in strains originating from three of our original intergrade strains, which, though having a common origin, had been separate for 104 generations covering a period of over four years.

EYELESSNESS IN CLADOCERA.

To the three cases of eyelessness in Cladocera mentioned a year ago, Dr. Banta has been able to add 10 additional cases. As in the cases reported before, the optic ganglia were partially or completely aborted, and in some cases the stem-like structures, which possibly represented aborted primordia of the eye and adjacent structures, were present on the front of the head in the young eyeless individuals. The sporadic occurrence of these eyeless individuals (7 were in a single bottle), their occurrence in some cases in bottles in which other abnormal individuals arose, and the lack of inheritance of the character, indicate that these are merely somatic alterations due to environmental factors. However, since eyelessness is a chracteristic of many cave animals, it is believed that any occurrence of such a trait should be carefully followed up.

STUDIES ON THE VASCULAR ANATOMY OF NORMAL AND TERATOLOGICAL SEEDLINGS OF PHASEOLUS VULGARIS.

Further studies on the vascular anatomy of normal and teratological seedlings of *Phaseolus* have been carried out by J. A. Harris, E. W. Sinnott, J. Y. Pennypacker, and G. B. Durham. These data have heretofore been treated from the purely anatomical side, but are to be used in connection with studies on natural selection, for which the experimental records are already available.

STUDIES ON HUMAN GENETICS.

HEREDITY IN ARISTOGENIC FAMILIES.

Dr. H. J. Banker has spent much time in collecting scholarship records in coeducational schools, with the aim of studying inheritance of special scholarship. An attempt was then made to analyze this material statistically. The data consisted of the records from two colleges and two secondary schools, and proved to be insufficient to furnish very definite conclusions by this method of treatment. The total population in the various tables that were constructed ranged from 87 to 354 and the number of children from 39 to 170, which in many cases were to be distributed in 6 categories. In specific subjects, as languages, mathematics, and history, as well as in general scholarship, there were indications of positive correlations between parents and children, but there appeared to be no evidence of Mendelizing factors, nor was there suggestion of significant variations of correlations with sex. Further data are sought for.

The work on a "eugenic" genealogy of a New England family was continued by Dr. Banker.

Heredity in Cacogenic Families.

Dr. A. H. Estabrook has completed the field work and writing up of his report on the Tribe of Ishmael. The year's work involved also the study of specific families, especially such as had removed into new environments farther west than Indiana, the main home of the tribe. One large group of this sort was found in Missouri and studied in detail.

In addition to his main investigation, Dr. Estabrook has made short studies (not cacogenic) of the Owen family of New Harmony and of the Merrill family of Vermont. Since in his studies at Indianapolis he has received every courtesy and assistance from the State and the head of the State Board of Charities, Dr. Amos W. Butler, and has been housed in the State Capitol, he has assisted the State in various ways outside of his main research. Thus he has met with the Indiana Committee on Mental Defectives at all its meetings during the year under review and advised with them. He has collaborated with their field investigators to the extent of advice and suggestions in their field work, and supervision of and responsibility for the scientific part of the report of the committee on its work in 1921 and 1922. He also gave a number of addresses and lectures before schools, churches, Rotary Clubs, social clubs, the State University, the Indiana Conference of Charities and Corrections, and others. Beginning December 1, 1922, Dr. Estabrook is undertaking a study of the "Highlanders" of the southern Appalachian Mountains.

Heredity of Body-Build.

During the past two years most of the Director's free time has been spent on a research into the heredity of body-build in man. This research has led to a study of the normal changes in body-build during development. A paper on this subject was published in Eugenical News for July. To secure data for the developmental curve of build, special measurements were made by Misses Louise A. Nelson and Margaret Babcock on 1,000 infants of known sex, age, and race at milk stations in New York City. In addition, Dr. Bret Ratner, of New York City, obtained for us daily measurements of weight, height, and chest-girth of 11 children at birth and each of the 10 days thereafter. For later life I made measurements on boys at Brooklyn Y. M. C. A.; Boy's Welcome Club; New York Society for Prevention of Cruelty to Children; Orphan Asylum, Brooklyn; Hebrew Orphan Asylum, Manhattan; New York Catholic Protectory; Children's Village; Hebrew Sheltering Guardian Society;

and Leake and Watts Orphan House. In many of these measurements I was assisted by Dr. Govaerts. About 1,500 boys were measured altogether. Acknowledgment is made of the cordial cooperation of the chief officers of these various institutions, who appreciated the need of developmental data for studies in inheritance of somatological characters. The analysis of the hereditary factors involved is nearly ready for publication.

Heredity of Multiple Sclerosis.

At the request of the Association for Research in Nervous and Mental Disease, I undertook to work up data on multiple sclerosis from the racial standpoint. With the aid of Miss Nelson, a number of families in New York City who show the disease were studied, and with the valuable assistance of Miss Mabel L. Earle a number of family histories referred to in the literature were discussed. Clear evidence was found of the presence of genetic factors.

The Heredity Factor in Human Tuberculosis.

During 7 months of the past year, Dr. Albert Govaerts, secretary of the Société Belge d'Eugenique, was a guest of the Eugenics Record Office. Dr. Govaerts brought to the office a special training in seriology which led him to undertake some experimental work on the effect of lens cytoloysins on the offspring of rats, with negative results. He paid special attention to a statistical study of tuberculosis as distributed in the families recorded at the Eugenics Record Office. A paper giving the results of this investigation is about to appear in the American Review of Tuberculosis. The main finding is clear evidence of the insufficiency of the contact theory to explain the high incidence of tuberculosis in certain families. The view of an inherited susceptibility to tuberculosis seems to be demonstrated by all of the facts of family history.

Assortative Mating in Man.

An analysis of the data on head-form, published by Frets, was carried out by Dr. Harris in cooperation with M. Albert Govaerts. It shows that for head-length, head-breadth, and cephalic index the coefficient of assortative mating is very low. The result is of importance in the general theory of assortative mating in that it shows that a character which has been regarded of considerable racial significance is not of importance in mate selection.

Variation, Correlation, and Racial Differentiation in the New-born Infant.

Dr. J. A. Harris and Dr. C. C. Little have under way an investigation of the characteristics of the new-born infant when the parents are of various nationalities. About 10,000 records from the Sloane Hospital, New York City, are being considered statistically.

GENETIC CONSTITUTION OF THE AMERICAN POPULATION.

Comparative Social Traits of Various Races.

On the hypothesis that racial traits are hereditary traits, an attempt was made by the Director to secure measurements of 10 such traits of different races represented in the New York City high schools. Two groups of data were obtained: one for 51 girls secured by the kind permission of Principal

Edward C. Zabriskie and the generous cooperation of Miss Rosemary F. Mullen, chairman of the biology department of the Washington Irving High School. The other group was of 148 boys obtained by Dr. R. S. Benedict, of the Stuyvesant High School. A study of the first group was published in School and Society, in October 1921. A second study of the entire collection has been made with the cooperation of Miss Laura Craytor.

Immigration and Deportation.

The Congress of the United States is seeking facts to guide it in its immigration policy. Mr. Albert Johnson, chairman of the Committee on Immigration and Naturalization of the House of Representatives, has asked the cooperation of the Eugenics Record Office, and Dr. H. H. Laughlin has been made a special agent of the committee for the purpose of an investigation into the "racial values" of the various immigrating peoples. To this end, facts concerning the racial (or more strictly national) origin of inmates of State and Federal institutions have been secured from 445 such institutions, which includes practically all of the larger and better organized. With the assistance of Miss Alice Hellmer, the results have been tabulated and will be duly reported to the committee of the House.

Provision is made in the immigration law for deportation of persons who become public charges within 5 years after arrival in the United States. Dr. Laughlin is securing, for the Congressional Committee on Immigration and Naturalization, facts concerning the practical working out of this law. In this cooperative study, returns have been received from 46 of the 48 State governments in reference to governmental laws and practices in the matter, and from 638 of the total 698 custodial institutions maintained by the State and Federal governments in the continental United States.

An analysis of the returns, as made by Dr. Laughlin, shows that a peculiar situation has developed in the United States in reference to the theory and practice of deportation. It is clear that the authority which deals with immigration and deportation is vested solely in the Federal Government, while the care of the socially inadequates of all types, in the United States, both native-born and alien, devolves primarily upon the several individual States. This situation of mixed authority and responsibility requires a system of more carefully adjusted coordination between the Federal and the several State governments, if an effective deportation practice is to be developed, with its expected relief to the congestion in State custodial institutions, and the prevention of contamination of future American stocks by the permanent introduction of excessive amount of defective alien germ-plasm. Largely on account of a marked failure of the States to secure the deportation of aliens who are deportable under the law, numerous aliens (over 200,000) are maintained by the several State governments. Dr. Laughlin has undertaken an estimate of the cost of maintaining such aliens, and this will be duly reported to Congress.

Eugenical Sterilization.

Dr. Laughlin has been engaged for about 10 years in collecting data on the operation of the "sterilization" laws which have been enacted by the various States. These laws not only constitute a remarkable episode in modern legislation, but they may well have a considerable importance in exercising a certain degree of control over the genetic constitution of the population of the United States. The data thus collected make an extensive volume which is being published in book form by the psychopathic laboratory of the municipal court of Chicago. Though such novel and intimately personal legislation has aroused very different opinions and emotions in people, the desirability of a judicial review of legislation having such potentital eugenical bearing can not be denied.

THE PHYSIOLOGY OF REPRODUCTION AND DEVELOPMENT.

The Relation of Endocrines to Reproduction and Growth.

Dr. Riddle has felt obliged to undertake this study because of difficulties and exceptions encountered in his earlier (but still unpublished) work on sex, and also because of its bearing on all genetic work on birds. It has received much of his attention throughout the year. Miss Mary Holmes has given valuable help with records, pedigrees, and computations concerned in these studies. Summaries for parts of this work are still incomplete. The results thus far obtained may be stated as follows:

(1) Desiccated glandular products given by mouth are usually without effect on birds; thymus, thyroid, and parathyroid are the chief exceptions. The normal effects of most of these glands can be obtained only by injection of extracts or suspensions.

(2) Additional data suggest that the thymus gland of birds largely presides over the secretion of egg-albumen and the egg-envelopes, and thus retains the function which it probably had in the lower vertebrates. On this view the thymus of mammals lost its function in the change to the mammalian mode of reproduction.

(3) McCarrison's conclusion is confirmed that the thymus persists throughout life (perhaps it should be said during reproductive activity) in the pigeon, and that the male thymus is nearly twice the size of the female thymus. Further, in agreement both with this difference in size of thymus in the two sexes, and with the current view that the thymus antagonistically affects the growth of the gonads, it has been found that the testes of the male pigeon are retarded in their growth for a longer (juvenile) period than is the (single) ovary of the pigeon.

(4) Moderate doses of thyroid substance are often capable of producing reproductive abnormalities in healthy birds. Delayed and diminished egg production and clutches of single eggs are among the observed irregularities. Though there is reason to believe that such individuals exist, we have failed thus far to find birds whose abnormalities of reproduction could be corrected by the administration of thyroid.

Other work of similar nature done by Dr. Riddle in cooperation during the year is as follows:

(5) The effects of repeated transplantation of suprarenals on young doves (with Dr. Tadachika Minoura). The adrenals of the birds into which transplants were repeatedly made did not measurably differ from the control, and the time of sexual maturity was nearly the same in transplanted and control groups. A notable amount of infertility and reproductive abnormality has been obtained from the first-generation offspring of the transplanted birds. The study of this point is being continued.

(6) The relation of the pituitary and its parts to growth, time of maturity, and phenomena of reproduction and sex (with Mr. J. R. Spannuth). The oral administration of the various preparations of this gland have little or no measurable effect on the growth curve. Injections of the extracts of anterior and posterior parts of the pituitary body have been made and growth curves obtained. Data for maturity and reproduction are not yet complete. This is practically the only type of study of this important gland which can be easily made on the pigeon.

Influence of Incretions of the Mother upon Embryonic Deaths of the Offspring.

A knowledge of the complete genetic output of a pair of pigeons presupposes that all of the number of eggs laid shall be known and that these shall in nearly all cases be hatched and reared. But in certain parts of our recent work with pigeons very large numbers of young are lost, owing to infertility, early cessation of development, death of embryo, etc. These developmental failures constitute one of the greatest obstacles to progress. During the past year important progress has been made in determining their cause.

Thus, it appears that some pigeons retain for variable, but abnormally prolonged, periods a small proportion of their eggs in the shell gland of the lower oviduct after the shell material has been placed upon the egg. Such egg-shells usually have an abnormal thickness, and they develop abnormally. The delay may reach the extreme of 100 hours. When it exceeds 20 to 24 hours, the developing germ usually dies at the one-half day stage. From a delay of 24 to 50 hours an embryo occasionally survives.

As stated below, such delayed eggs are easily forced from the oviduct by the administration of pituitrin, and it is possible that the failure to expel the egg is due to disfunctioning of the bird's pituitary gland.

In a third series of cases evidence has been obtained which indicates that death of the embryo sometimes results from the very early break or rupture of an inefficient vitelline membrane. The eggs of only a few birds exhibit this characteristic, but it is usually exhibited by several or many of the eggs of a particular bird. The rupture and death occur most commonly at the one-day or two-day stage. After a real rupture of the yolk-membrane, and after significant outflow of yolk, continued life in the embryo is impossible.

In a fourth group of cases, series of embryos from the same parents are found dead at the three-day to four-day stage, and, though these embryos seem otherwise normal, the amnion has failed to complete its development and the incompletely inclosed embryo has become adhered to the shell. Dr. Riddle concludes that, though our evidence is not conclusive on the matter, the initial failure is that of the development of the amnion and that adhesion to the shell and resultant death are subsequent events. Data concerning the more remote basis of the improper development are being collected.

A fifth group of cases is formed by those ova which are not received into the oviduct, but pass into the body-cavity and there fail to develop. It has been shown that the injection of small amounts of pituitrin (the active principle of the pituitary gland) during the first few hours after the entrance of an ovum into the upper oviduct will usually cause this yolk to be returned to the body-cavity. These results suggest that a temporary hypersecretion of the pituitary gland by the mother bird may be the cause of these ovulations into the body-cavity.

These observations concerning the relation of endocrine glands to the various causes of early embryonic death indicate that many of the disorders of reproduction are traceable to abnormal incretions of the mother.

Another line of investigation of early embryonic death has been made in cooperation with Mr. Embree R. Rose. This is a study of various elements of nutrition as possible causes of reproductive abnormalities and embryonic death. This work was nearing completion when reported for last year. The final results confirm the statements made at that time—the notable reproductive abnormalities which appear in significant numbers in our birds can not be ascribed to deficiencies of the common and well-known factors of diet.

A Simple Method for Obtaining Premature Eggs from Birds.

A paper dealing with this subject has been published by Dr. Riddle. By means of hypodermic injections of small amounts of pituitrin, the eggs are laid in from 4 to 30 minutes after injection.

By this method eggs at various stages of immaturity, including successive eggs from the same parent, are made easily available for studies on the earlier stages of embryonic development, for experimental studies on these most modifiable stages, for chemical studies on various parts of the egg with less than the usual opportunities for change and admixture, and for isolating the functions of the various parts of the bird's oviduct. It is probable also that under certain conditions or limitations this reaction of the dove's oviduct, living and *in situ*, would be useful as a means of standardizing solutions of the active principle of the pituitary gland.

Decrease of Blood Sugar of Pigeons During Prolonged Inactivity and Close Confinement.

This study was made by Dr. Riddle in cooperation with Dr. H. E. Honeywell. It is well known that common pigeons kept confined in small cages usually do not produce eggs. The reason for this has been far from clear. It has, however, been shown by Lusk that dogs kept in the laboratory and in very confining quarters undergo a decrease in their basal metabolism. Since we had already learned that a high mobilization of sugar occurs at ovulation periods in pigeons, we considered it probable that the close confinement of these pigeons brought about a reduction in their metabolism similar to that found by Lusk for dogs, and that this lowered metabolism should express itself in a lowered blood sugar. Three series of tests made on 25 common pigeons show a fall of the blood-sugar value from 180 mg. per 100 c. c. of blood to 126 mg. as the result of three weeks of close confinement.

Variation and Correlation of Fecundity in the Domestic Fowl.

For the past several years this Department has had under way a detailed statistical investigation of the various phases of the problem of variation, correlation, and the inheritance of fecundity in the domestic fowl.

From the practical side, one of the most important results of these investigations has been the demonstration that the egg records of various periods of the year are so correlated that it is possible to predict the future egg record or the annual egg record of a bird from the records of short periods of time with a considerable degree of accuracy. This conclusion has been based primarily on studies of the White Leghorn, for which more data are available than for any other breed. It has seemed very desirable to determine whether similar laws hold for the other breeds of poultry.

Studies of the White Wyandotte breed by Dr. Harris and of the Rhode Island Red breed by Dr. Harris and Professor Goodale, of the Massachusetts Agricultural Experiment Station, are now in press. While the numerical values of the statistical constants differ somewhat from those found for the White Leghorn, the results confirm in all essentials those already reported in earlier Year Books and presented in detail in *Genetics* and other journals. The possibilities of the prediction of the egg production of longer periods from the recorded egg record of shorter periods is, therefore, not limited to one peculiar breed, but is in all probability equally applicable to all the more important commercial breeds.

The foregoing studies have been limited to first-year production. Dr. Harris and Professor Harry R. Lewis, of the New Jersey Agricultural Experiment Station, have shown that similar correlations between the egg record of various periods of the year obtain in the second laying year of the White Leghorn fowl. Thus it should be possible to predict the second-year annual production from the records of the individual months of the second laying year, just as it has been shown to be possible to predict the annual production of the first laying year from the records of individual months.

A portion of the results of an investigation of the relationship between the records of the individual months of the first year and the records of the individual months of the second year are now in press, under the joint authorship of J. A. Harris and Harry R. Lewis. As pointed out in the last Year Book, the results of these studies tend to throw considerable doubt upon the importance of the so-called winter cycle as a distinct entity of importance in the inheritance of fecundity in the fowl. These investigations are now showing that there are definite laws underlying the distribution of the inter-mensual correlations of the first, of the second, and of the first and second years. These will be ready for publication in the near future.

In the course of the investigation of the relationship between the egg production of the first and second years, it became evident that there must be a fairly close correlation between the time of beginning and of cessation in the first and second egg-laying years of the bird's life. A special investigation was, therefore, made of this problem. The results of this study show that there is not merely a correlation between the time of beginning of laying and the time of cessation of laying in the first and second years respectively, but that there is a definite correlation between the time of cessation of laying in the first year and the beginning of laying in the second year. The results of this study are now in press in *Genetics*.

Differences in Rate of Growth of the Races of Mice.

During the summer, Professor W. H. Gates, of the State University, Baton Rouge, Louisiana, has been studying the rate of growth during the first three weeks of young mice of the Japanese waltzing variety, of descendants of the X-rayed non-waltzing and of control non-waltzing mice, with a view of determining whether or not a racial difference in the rate of growth exists. The data comprise observations made on about 1,000 animals.

CORRELATION BETWEEN PHYSICAL AND MENTAL DEVELOPMENT IN MAN.

As a member of the committee for the study of the problem of feeblemindedness at Letchworth Village, the Director made measurements and other physical observations on 100 idiot boys at that institution. He was assisted by Dr. Govaerts and Miss L. A. Nelson. The superintendent, Dr. Charles S. Little, afforded the investigators every courtesy. The measurements thus obtained bear upon the problem of the specific action of endocrine disfunctioning upon development and the inheritance of such disfunctioning. An analysis of some of the data collected has been made by Dr. Bertha E. Martin and is now nearly ready for publication.

OTHER INVESTIGATIONS.

STUDIES ON PHYSICO-CHEMICAL PROPERTIES OF VEGETABLE SAPS.

Physico-chemical properties of the tissue fluids of alpine and subalpine vegetation.—Work has been continued by Dr. Harris on the data secured by Professor and Mrs. Lawrence (through the courtesy of Professor Clements, who allowed Dr. Harris to utilize his Alpine Laboratory as a base of operations) in the Pike's Peak region. Further determinations have been secured from Mount Nebo, of the Wasatch Range, Utah.

Physico-chemical properties of the tissue fluids of coastal vegetation.—These studies have been continued by Dr. Harris as opportunity offered, along the lines laid down in the last Year Book of the Institution. Some field work has been done, but attention has been chiefly devoted to analytical work.

Studies on the physico-chemical properties of the tissue fluids of cereals as grown under dry-farm and irrigation agriculture.—These investigations have been continued by Dr. Harris at the Nephi substation and at the Utah Agricultural Experiment Station, Logan, Utah. The purposes of the investigations have been sufficiently outlined in the last Year Book. In 1922, Mr. W. F. Hoffman, Mr. A. H. Johnson, and Mr. R. D. Evans were largely responsible for this work under Dr. Harris's direction.

Studies on the evolution of the Loranthaceæ and other phanerogamic parasites.—These studies have been continued, as outlined in earlier reports, as occasion has offered.

BIOMETRIC METHODS.

Dr. Harris, in cooperation with Messrs. Blakeslee and Belling, has completed for publication a set of tables showing the probability that a culture of a given size is capable of producing only individuals of the dominant type.

Formulæ for the determination of the correlation between a variable and the deviation of an associated but not dependent variable from its probable value have been determined and are now in press.

ADMINISTRATIVE RECORD.

ARCHIVES OF THE EUGENICS RECORD OFFICE.

The care of the archives has been in the hands of Dr. Elizabeth C. Muncey, who was assisted by the Misses Helen Bowen, Helen Brown, and Margaret Martin, as indexers. Owing to the fact that our accumulation of archives is exceeding the capacity of our archive room, it became necessary to remove some of the filing cases to the basement. They are thus rendered relatively inaccessible and their distance from the main files adds to the expense of administration.

An estimate of the extent of the records and their index, made as of September 1, 1922, is as follows: 878,971 cards in the index: 1,496 books in archives. The field reports (F) number 53,998 sheets; the special traits file (A) 23,181 sheets; the records of family traits (R) and (M) files, 4,679 parts.

During the summer we had the assistance of a number of college students in preparation of material for the archives and in the analysis of records. Misses Laura Craytor, Esther Powell, and Katherine Belzer collated data on racial social traits, eye and hair color, and somatic proportions of idiot children.

Collection of Data.

Excellent progress has been made this year in securing the cooperation of college teachers in introducing into their courses of biology, sociology, and psychology the exercise of filling out family-history schedules. The Department offers to furnish the blank schedules in duplicate, with the understanding that one copy filled out will be deposited at the Eugenics Record Office. The number of collaborating teachers in this service during the year was 23, too large to acknowledge adequately individually. The number of records of family traits thus supplied totals 552. The teachers and students have found the exercise a valuable one; for the most part the students have evidently done the work with thoroughness and accuracy.

Especial mention must be made of the gift by Dr. Harold Bowditch of manuscript anthropometric records and a number of composite photographs made by his father, the late Dr. Henry P. Bowditch, Professor of Physiology at the Harvard Medical School and a pioneer in biometry in America. Dr. Bowditch also sent us a number of rare biometric books from his father's library and secured the gift from Mrs. Charles P. Bowditch of her husband's genealogy of the Pickering family. From Colonel D. Cornman, U. S. Army, were received 2,000 manuscript pages of Leighton genealogy and 11 printed genealogies and town histories. Professor W. M. Goldsmith, of Southwestern College, Kansas, secured for us 938 records and presented an exhibit, "The Catlin Mark." Dr. R. C. Benedict secured for us 153 eye and hair color schedules and many data for a further study of racial social traits. Mr. Albert Wiggam secured for the Office 250 twin schedules and numerous photographs. The largest collection of records of family traits was one of 268 sent by Professor W. M. Barrows, of the Ohio State University. The Whittier State School has continued to send carbons of all their extremely valuable case and family histories.

Training Corps.

Fifteen women and three men were trained for eugenical field work June 28 to August 8. Of these, 8 have secured or are considering appointments in eugenical field work or related positions. To date 233 persons have received this training, which consists chiefly of laboratory work and clinics in institutions. This body of trained workers has not only contributed greatly to the building up of our records, but in other respects has proved indispensable to eugenical research.

SECOND INTERNATIONAL CONGRESS OF EUGENICS.

This Department was called upon to assist in organizing and carrying through this congress, which met September 22 to 28, 1921, at the American Museum of Natural History, New York, and for one day at Cold Spring Harbor. Dr. C. C. Little served as secretary-general and Dr. H. H. Laughlin as chairman of the Committee on Exhibits. The congress was supported by leading geneticists and by investigators in eugenics, as well as by numerous persons interested in the social applications of these subjects. The proceedings of the congress are being published. As there were 500 members of the congress and over 5,000 persons visited the exhibits, it is thought that the participation of the Department in this congress was justified by the increased popular interest awakened in genetical research.

SPECIAL ACTIVITIES OF AND CHANGES IN STAFF.

A severe loss has been experienced by the Department in the resignation of Assistant Director Little on July 1, to become president of the University of Maine. During his three years at this Department he made some discoveries of fundamental importance and stimulated the spirit of cooperation not only inside the Department but also between the Department and geneticists generally. Fortunately, we may look forward to his continued association with this department in his genetical research.

The work of the Department is gradually crystallizing about a few main centers: First, the mammal work, of which the experimental work is now focused upon mice, both because of their rapid breeding, their relatively slight cost, and the large amount of work already done on them. Here Doctors Little and MacDowell are primarily in charge, with a number of assistants and summer collaborators. The experimental work on mammals fits in closely with the eugenics work, which is largely statistical, and in which Dr. Harris's biometric laboratory is of special assistance. Besides Dr. Harris, the principal investigators in this group are the Director, Doctors Laughlin, Banker, and Estabrook, Miss Louise A. Nelson, and assistants. Second, the chromosome work on *Datura* under the charge of Dr. A. F. Blakeslee, with Dr. John Belling cooperating in the cytological work and Mr. Farnham assisting in garden and field and a number of assistants and summer collaborators; and on Diptera by Doctors Metz and Anderson and assistants. In addition, there is the sex work on pigeons by Dr. Riddle and his assistants, and on Cladocera by Dr. Banta, with an assistant and the temporary collaboration of Mr. L. A. Brown.

GEOPHYSICAL LABORATORY.[1]

By Arthur L. Day, Director.

THE DIFFERENTIATION OF THE MAGMA.

The crust of the earth, so far as it is known, is made up almost exclusively of rocks formed by the consolidation or crystallization of molten matter—the so-called igneous rocks. There is, in addition to the igneous rocks, only the relatively insignificant veneer of detrital material resulting primarily from their disintegration under the action of the weather. These fundamental igneous rocks have naturally occupied the attention of the geologist since the beginnings of his science.

One of the earliest features recognized in connection with them was the fact that the igneous rocks are not all alike, though associated so intimately as to indicate a common origin. They vary from mass to mass and from place to place within a single mass. Apart from the purely scientific interest in this diversity of types, it is of importance in other respects. It is found for example, that some types give rise to a soil capable of supporting a rich vegetation and others to a soil that is nearly barren. Certain metallic ores are found in association with some types, while other types contain quite different ores or none at all, so that the processes that have led to the differentiation of the various types of igneous rocks really lie at the root of most human activities.

It is becoming increasingly apparent that the production of a number of types of igneous rocks from a single molten mass must be connected with the process of crystallization. If a certain substance crystallizes out from a liquid mixture containing it, the remaining liquid must perforce be impoverished in that substance. The mere fact that the substances contained in any such liquid mixture must crystallize from it in a certain order is, therefore, sufficient to indicate variation of the crystalline mass from place to place.

The large number of investigations of mineral systems that have been carried out at this Laboratory furnish complete information concerning the crystallization of liquids belonging to certain of these systems and the kind of variation to which crystallization may give rise. Synthetic studies of these systems have revealed the existence of a principle of first importance in explanation of the variation of composition in igneous-rock masses. It has been noted in a number of these systems that after the separation of crystals of a certain kind the remaining liquid may later, in the cooling process, react with these crystals to modify or completely change their composition. Such reactions must likewise affect the composition of the liquid, so that the further course of the liquid, the crystalline products that form from it, and the temperatures at which they form will be affected in proportion to the freedom with which these reactions take place. The conditions attendant upon crystallization in turn govern the freedom of these reactions, so that through the working of the reaction principle the crystalline products of a magma are rendered responsive to surrounding conditions, particularly to the rate of cooling.

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[1] Situated in Washington, District of Columbia.

The principal minerals of igneous rocks can be arranged as reaction series, such that any member of the series is produced from the preceding member by reaction with the liquid magma in the manner above noted. The plagioclase feldspars, together with potash feldspar, constitute one series, and the olivines, pyroxenes, amphiboles, micas, and quartz constitute another series. A basic magma may give rise simply to calcic plagioclase and pyroxene, if quickly cooled, whereas the same magma, slowly cooled, may yield a long chain of products embracing all the minerals enumerated above. In other words, diorite, granodiorite, granite, and other rock types may form by differentiation from a basic magma in virtue of the existence of this unidirectional reaction relation among the mineral products.

Another possible cause of variation of igneous masses is that due to the incorporation in magmas of foreign rocks. The importance of this action has long been a subject of discussion, some assigning to it a dominant role and others denying its very existence. The heat required for solution has been considered too great to be supplied by the liquid magma; but a consideration, from the viewpoint of the reaction principle, shows that magmas can incorporate large quantities of foreign matter by reacting with it. If the magmas and the various types of foreign material are considered with respect to their position in the reaction series, it is found that a magma can not dissolve foreign inclusions belonging at an earlier stage of the reaction series than the phases with which it is saturated, but can and will react with such inclusions to convert them into the phases with which it is saturated. On the other hand, foreign inclusions belonging to a later stage in the reaction series than the phases with which the magma is saturated can be dissolved by the magma by a sort of reactive solution, a certain amount of the phase or phases with which the liquid is saturated being simultaneously precipitated. This deduction from the results of experimental work is in accord with the observations of the field geologist and at the same time permits an evaluation of the relative importance of solution as compared with spontaneous differentiation. We have found that the material, in order to pass into solution in a given magma, must belong at a later stage in the reaction series than the dissolving liquid; in other words, must be of a composition toward which the liquid changes by spontaneous crystallization-differentiation. Plainly, then, the crystallization-differentiation is the dominant factor in bringing about variations in igneous rocks, for through it variations may come about spontaneously without the intervention of any foreign material, and at the same time it completely controls variations due to the solution of foreign matter. (See reviews of papers 451 and 459 following.)

VOLCANO STUDIES.

In recent years the attempt has been made not only to study and reproduce in the laboratory the rock-forming processes through which the great body of igneous rocks comprising the visible crust of the earth came into being, but also to study the natural processes in the regions where they are still going on, namely, in the volcanoes. Two researches in this latter field have been completed recently, which add much to our knowledge of these complicated natural phenomena. The first of these (Allen and Zies) records the results of the field and laboratory work carried out by the chemists of the expedition sent to the Katmai region in 1919 by the National Geographic Society, in collaboration with the Geophysical Laboratory. It contains a general description of the fumarolic area of the Katmai region, and also the distinctive characteristics of the fumaroles located in the pumiceous deposit of the Valley of Ten Thousand Smokes and its branches. A detailed account is also given of the field and laboratory work, together with deductions based thereon.

The highest fumarole temperatures (650° maximum) followed a discontinuous zone about Baked and Broken Mountains, with a salient extending out into the main valley from Broken Mountain. The borders of the fumarolic area were usually characterized by low temperatures. A perusal of all the temperature data obtained by the expeditions of 1917, 1918, and 1919 strongly indicates that the fumarolic activity is declining. This is not at all surprising when one considers the great cooling effect of the drainage water from the mountain slopes that finds its way into the pumice and reappears as steam issuing from the fumaroles, or as vapor rising from the valley floor, as well as in the hot streams that drain the valley. The fact that great fumarolic activity and unusually high temperatures still persisted in a number of the fumaroles 7 years after the eruption is much more surprising. It shows definitely that the heat given off by the fumaroles must be derived from a deeper source than the ejected pumice.

Steam is the predominant constituent in all the gases examined, and varies from 99.45 to 99.85 per cent by volume. The most important of the other gases are HCl, CO_2, H_2S, N_2, HF, and sometimes CH_4. Minor constituents are O_2, CO, A, and NH_3. Ammonia generally occurred in the form of chloride and probably fluoride. Sulphur dioxide may occur in some places, but was not detected. Judging by the incrustations, sulphur must be a constituent of the gases and, more rarely, the sulphide of arsenic.

Samples of soluble gases collected by Shipley (1918) and examined in the Geophysical Laboratory indicate that the percentage of HCl reaches, on the average, the same order of magnitude as CO_2 and HF, and comparable with that of H_2S and N_2. This is borne out by the relatively large amounts of fluorine found as fluoride in the incrustations and is unique in the annals of volcanology.

The ratio of argon to nitrogen is practically the same in the gases as it is in the atmosphere, and the inference is that they are both of atmospheric origin. If so, the associated oxygen has been largely absorbed. The amount of heat generated in the oxidation of the volcanic gases by this small volume of oxygen can be only an insignificant portion of the total heat given out by the fumaroles.

The water-vapor in the gases is largely derived from surface water, as appears from the following observations: (1) The quantity of water-vapor in the gases varies considerably and the variations appear to be closely related to local variations in drainage in nearly all cases. (2) The porous nature of the pumiceous deposit permits the absorption of a great amount of the drainage from the mountain slopes. A calculation based on annual precipitation and on the amount of water carried out by the streams shows that much of the drainage does not reach the streams and is in all probability returned to the atmosphere as vapor through the fumaroles. This is also borne out by the fact that all the streams draining the valley contain much more water in their upper courses than at their outlets. (3) Decidedly the smallest amount of water in any of the gases was found in those issuing on the west slope of Novarupta a short distance from the only point where the lava body reaches the surface. (4) The fumaroles below the surface of the ground appear to be accessible to air; if so, they should be accessible to water-vapor as well.

It is also shown that in none of the fumaroles are combustible gases burning at the surface. The observed negative temperature gradients were in all probability due to hot lateral gas currents.

No relation between temperature and gas composition was observed, except in the case of the soluble gases. These are usually very small in amount in fumaroles of low temperature and relatively high as compared with the "insoluble" gases in the hotter fumaroles. A survey of the literature indicates that magmatic gases are not necessarily uniform in composition and that the original gas mixtures are modified by a number of secondary agencies only partially dependent on temperature. The generalization of Deville and Fouqué that magmatic gases are everywhere uniform and that their composition is subsequently modified by no variable agency except temperature seems untenable.

The second volcano study was begun in the second year (1915) of the recent eruptive activity of Lassen Peak in California and has been continued intermittently since that time, partly in the field and partly in the Laboratory.

Compared with other volcanic outbreaks of which we have a record, Lassen Peak has not during its recent activity displayed unusual phenomena or excessive violence. This activity may be summarized as a series of explosions in the summit crater, beginning in May 1914 and continuing at intervals of 2 or 3 days until the same month of 1915, during which period both the violence and the duration of the explosions generally increased. The outbreaks culminated in 3 days of nearly continuous explosions, during which red heat was once visible on the top of the mountain (May 19), the lava plug forming the floor of the crater was pushed up 300 feet or more to the level of the crater rim, and finally two horizontal blasts of extreme intensity broke through on the northeast flank of the mountain beneath the plug, laying waste the valleys of Lost Creek and Hat Creek for a distance of 4½ miles. These two blasts occurred on May 19 and 22, 1915, and swept out every vestige of vegetation in the center of their path, including nearly 5,000,000 feet of original forest timber. At the sides of the valley, down which the blasts passed, the trees were blown down but were not carried away, so that they remained lying upon the steep sides of the inclosing valley, pointing directly away from the crater, thereby showing clearly the point of origin of the blast which blew them down. There was no eye-witness of the horizontal blasts either on May 19 or May 22.

Following these outbreaks, the activity of the volcano slowly subsided, the last eruptions of any magnitude occurring in May of 1917.

The mechanism of these horizontal blasts is interesting. At the beginning, or shortly before the activity of the 19th, the crater floor was raised from below until it stood nearly level with the crater rim. Had it gone higher, the plug would undoubtedly have been dislodged entirely from the vent and a flow of lava would have resulted. As it was, the enchained pressure of volatile matter (mainly water) within the mountain appears to have found vent on the 22d without actually blowing off the top of the mountain and thereafter to have remained powerless to open the main crater conduit. It was as though the lava plug with which the volcano had remained sealed for so many years had been started upward by pressure from within, which had then found release at the weakest point in the inclosing chamber. This happened not to be through the plug itself, but below the plug on the northeast side of the mountain, much as a gas explosion in a coal-burning stove might do, raising the lid and escaping in a horizontal blast from beneath it. After the emergence of these horizontal blasts the pressure was released and the lid collapsed. Its present appearance indicates rupture by such forces at a great many points of the exposed surface.

The mechanism of this entire sequence of volcanic activity can, I think, be inferred quite simply from the phenomena which have been described and from an appropriate application of the laws of physical chemistry. The great volcanic clouds which characterized the explosions were mainly of dust-laden steam. There is extremely little evidence of the participation of sulphur or other chemically active ingredients from beginning to end of this series of outbreaks. Compared with other volcanoes which have been studied, the volcanic phenomena at Lassen Peak occurred at comparatively low temperatures, certainly not above red heat. It should be noticed also that Lassen Peak is located in a region of considerable rainfall, that the summit crater is almost never free from snow, and that several streams of considerable size have their sources high on the flanks of the mountain. We are therefore dealing with a cooling volcano hearth in a region of abundant water-supply.

Considering such dynamic systems, it is usual to assume that temperature and pressure rise and fall together. If the temperature were to rise, the pressure would be increased and if it were to fall the pressure would fall with it. In such reasoning, however, we overlook a vital factor in the consideration of silicate systems in the presence of considerable quantities of water. Laboratory measurements have shown that silicate solutions (rock magma, lava) of high silica-content easily take up 10 to 15 per cent of water when in liquid condition under pressure and carry it in solution. In accord with this we find in nature occasional pitch-stones and obsidians, which have cooled from the magma without crystallization, also containing 10 per cent or more of water. On the other hand, crystalline rocks, as shown by the thousands of analyses made of them, contain no more than 1.5 per cent of water. In order to crystallize, therefore, a high-silica magma containing 10 per cent of water must divest itself of more than 80 per cent of this water in the process of crystallization. Such a large proportion of the water-content set free in the hot volcano chamber will increase the pressure enormously, even though the crystallizing operation is a cooling process.

By way of illustration of this, silicate mixtures have been prepared in the Laboratory, inclosed in bombs with a sufficient quantity of water, and the pressure measured over a series of falling temperatures. It has been demonstrated, for example, that a simple mixture of silica, potash, and water, which begins to crystallize at 500° C., will discharge this water when the temperature is lowered from 500° to 420°, and the water thus set free will immediately develop a pressure appropriate to that high temperature. In this system the pressure may increase sevenfold (from 50 atmospheres to 340 atmospheres) in cooling through this interval of 80°.

Without going further into the physical-chemical details, this process finds direct application at Lassen Peak. The magma is an andesite high in silica, and so far as we have evidence of the heat conditions it is in process of crystallization at a comparatively low temperature. The available water in the region is abundant to support the assumption that the percentage of water carried in the magma is large. The enormous quantities of water given off in the 300 or more explosions of record, some of which continued for several hours, still further supports this assumption.

It remains to consider how such a process can produce a succession of explosions of gradually increasing intensity up to a culminating point and then gradually subside.

Suppose that the temperatures within the mountain were relatively low, as every indication during the period of explosive activity seems to establish. Then crystallization was probably proceeding at a very slow rate in a magma of high viscosity which very probably was much undercooled. Suppose, further, that into this inert mass there was suddenly introduced, through cracks at the top, a body of water, under a pressure-head appropriate to the height of the mountain, which was speedily transformed to steam, which, under such circumstances, we know is quickly absorbed by the magma. The first effect of such an intrusion is to cause a considerable increase in the rate of crystallization. Water is coming in at a low pressure from one source, and in consequence of it water is released from another source (out of solution) at a high pressure. An increased rate of crystallization means an increased rate of setting free of the water-content already impounded in solution in the inert lava. The resulting pressure increase might be expected to seek an outlet through the opening which had thus been broached in the crater floor, and a small explosion might result. An undercooled lava system, though inert if cool enough, is unstable, and once it is set in action through increase of fluidity in this manner the tendency to reach equilibrium (through crystallization) is strong. Consequently, the action here indicated is likely to proceed rapidly and the rapidly accumulating pressure to find relief in successive explosions depending for their magnitude and frequency directly upon the rate of advancing crystallization and the increasing amount of participating lava as the successive explosions expose greater masses to the new and favorable conditions. This seems to account well for the low intensity of the initial outbreak and the gradual increase in volume and intensity as the crater floor was shattered by successive explosions and greater quantities of water were admitted to the volcano hearth, bringing an increasing quantity of crystallizing magma into an action which eventually becomes more or less self-perpetuating until all the available uncrystallized lava is participating. Then follows the culmination and subsidence.

This analysis, if correct, might lead to two alternative results. The breaking down of the resistance of the containing envelope, that is, the mountain itself, might happen either from without or from within. If the release had come solely through accumulated pressure within, which eventually became adequate to overcome the normal resistance of the mountain, then a terrific explosion must have resulted through which the entire accumulation of energy would have found release in a single catastrophe. This obviously was not the case. If, on the other hand, the resistance of the mountain to the accumulated pressure within had somehow been weakened slightly by action from without, such as an earthquake crack, and this development of structural weakness had been followed by a succession of explosions extending it gradually, then we would seem to reach the counterpart of the present phenomenon.

ATOMIC STRUCTURE OF CRYSTALS.

During the past year there has been prepared for publication a complete elaboration of the 230 space-groups which form the basis of all studies of atomic structure in crystalline matter.

With the gradual introduction of orderly methods of determining crystal structures by the use of X-rays, a thorough analysis of the systems resulting from an application of the theory of space-groups has become increasingly necessary. Publication No. 318 of the Carnegie Institution of Washington, entitled "*The Analytical Expression of the Theory of Space-groups,*" is intended to supply such an analysis for general use in crystal-structure study. In a complete and unique determination of the structure of a crystal, as opposed to the mere suggestion of a possible arrangement of atoms which will conform to certain limited data, it is imperative that the investigator have available a knowledge of all of the atomic arrangements that are possible from the standpoint of the observed symmetry of the crystal. This information is furnished by a study of all of the special cases of the space-groups. Because in the study of a single crystal it is usually necessary to consider several space-groups, and also because the available methods of study are gradually gaining the power to attack successfully other systems than cubic crystals, it has seemed not only expedient but necessary to make a complete treatment of the space-groups of all crystallographic symmetries.

Particular care has been taken to express the results of this study in appropriate detail, not only for facility of reference but also because it is realized that the majority of future students of crystal structure will hardly wish to take the time to become conversant with the details of the theory of space-groups and so will be in a position to use results of the theory only so far as they are completely tabulated. Although the primary purpose of the work has been the presentation of a complete analytical expression of the space-groups, the almost total absence from English literature of any discussion of this phase of geometric theory has suggested the desirability of incorporating a brief discussion of the characteristics of the space-groups themselves for the benefit of those who may desire to gain some idea of their nature without wishing to study the theory itself in detail. A discussion of so much of the material as appeared necessary to accomplish this purpose has consequently been included in short chapters prefatory to the principal tabulations.

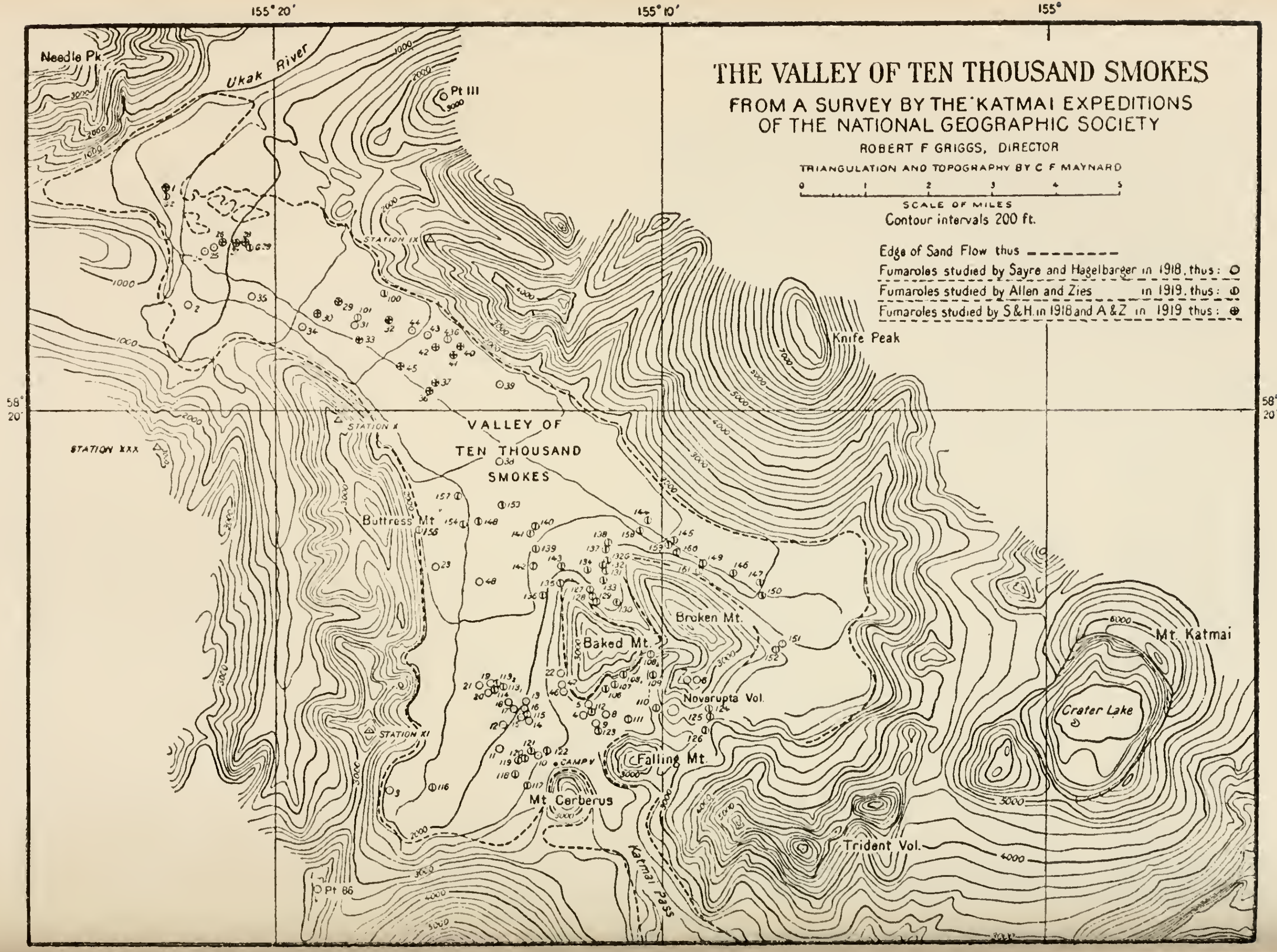
This careful elaboration of the possible group patterns should be of the greatest service to students of atomic structure. Indeed, since the preparation of such a volume became known a number of requests have been received for advance copies of portions of it, and photostat copies of many of the manuscript tables have been supplied to workers in this field.

GRAVITY MEASUREMENTS.

In view of the Director's responsibilities as Chairman of the Advisory Committee in Seismology, the Laboratory has taken much interest in the problem of a comprehensive study of California earth movements. The particular task which the Laboratory undertook was the design of a new apparatus for the determination of the constant of gravity, in cooperation with the U. S. Coast and Geodetic Survey.

The studies heretofore made of the distribution of density and isostatic adjustment have depended upon measurements with pendulums of different designs and with somewhat ponderous mounting, so that it requires in general about a week for a competent determination of the gravitation-constant at a particular point, and only such points as are reasonably accessible to an automobile truck, upon which the apparatus must be transported, can be included in the plan. For a competent study of isostatic adjustment in a region where the anomalies in the value of g are unusually large, and where the differences of land elevation are very abrupt, a great many more determinations are necessary than have heretofore been possible. To secure a proper number of observations and to include among them comparatively inaccessible mountain regions, it is necessary to design a much less cumbersome instrument, if possible without any loss of precision. During the past year preliminary experiments have been undertaken in this direction.

Brief reviews of the papers published by the members of the Laboratory staff during the current year will be found on the following pages.


THE VALLEY OF TEN THOUSAND SMOKES
FROM A SURVEY BY THE KATMAI EXPEDITIONS OF THE NATIONAL GEOGRAPHIC SOCIETY
ROBERT F GRIGGS, DIRECTOR
TRIANGULATION AND TOPOGRAPHY BY C F MAYNARD
0 1 2 3 4 5
SCALE OF MILES
Contour intervals 200 ft.
Edge of Sand Flow thus
Fumaroles studied by Sayre and Hagelbarger in 1918, thus: ○
Fumaroles studied by Allen and Zies in 1919, thus: ⦶
Fumaroles studied by S & H. in 1918 and A & Z in 1919 thus: ⊕
155° 20′
155° 10′
155°
58° 20′
Needle Pk.
Ukak River
Pt III
STATION IX
STATION X
STATION XXX
STATION XI
Knife Peak
VALLEY OF TEN THOUSAND SMOKES
Buttress Mt
Baked Mt.
Broken Mt.
Novarupta Vol.
Falling Mt.
Mt Cerberus
CAMP V
Katmai Pass
Trident Vol.
Mt. Katmai
Crater Lake
Pt 86
1000
2000
3000
4000
5000
6000
7000

PUBLICATIONS.

(416) Genetic features of alnoitic rocks from Isle Cadieux, Quebec. N. L. Bowen. Am. J. Sci., 3, 1-34. 1922.

An occurrence of alnoitic rocks at Isle Cadieux near Montreal, Canada, is found to consist principally of monticellite alnoite, a newly recognized (not a new) rock type. Besides this type there is a variety, consisting almost exclusively of melilite and biotite, which is apparently new.

A study of the relations of the minerals indicates that the rock originally consisted of augite and chrysolite and was nearly completely consolidated as such. These minerals were then attacked, with lowering temperature, probably by their own interstitial liquid as it changed in composition, and they were replaced by monticellite, melilite, and biotite, with marialite, perovskite, and titaniferous magnetite as minor products of the reaction. The monticellite is itself replaced by melilite and biotite, and the melilite-biotite rock is the end-product of the replacement. This replacement was accomplished by an alkalic liquid (magma) which formed monticellite from augite by desilicating it, and later gave rise to melilite and the more definitely alkalic mineral biotite.

The melilites are both positive and negative and are sometimes conspicuously zoned, with a positive core, an isotropic intermediate zone, and a negative rim.

In an experimental part of the paper, equilibrium in mixtures of nephelite and diopside is determined. It is found that, from intermediate mixtures, forsterite and melilite are the first products to crystallize, and the melilites so formed are analogous to natural melilites in composition and optical properties. It is thus proved experimentally that nephelite reacts with diopside to form melilite, a reaction analogous to that which is considered to have taken place between augite and alkalic liquid in the natural rocks. This reaction is of the nature of a desilication of the diopside; and while the formation of monticellite in this manner has not been demonstrated in the relatively simple experimental mixtures, the demonstration of desilication of diopside in these mixtures is believed to give support to the idea that monticellite is so formed from augite in the more complex natural mixture.

An outstanding difference between the natural, replacing (reacting) liquid and the artificial mixtures is the presence of potash and water in the former. As a result of this difference the reaction products, instead of being forsterite and melilite, were, in the natural rock, biotite and melilite, with monticellite as an intermediate step. In fact, chrysolite, originally present, was itself a principal source of biotite. The liquid, as modified by the reaction, passed on and possibly gave rise to analcite dikes.

It is probable that monticellite occurs fairly frequently as an igneous-rock mineral in rocks related to those described. Reexamination of the original alnoite shows its presence there with apparently a similar relationship. Even the pure lime olivine itself (βCa_2SiO_4) has been found in a related rock from Tasmania, a fact to which attention is here directed because it appears to have been overlooked in general petrologic literature.

Such lime-rich minerals, including also melilite and the related minerals, garnet, vesuvianite, and others, may be considered to have formed in alkalic magmas as the result of desilication of the more normal cafemic molecules (metasilicates). Their presence in alkalic rocks may therefore be the result of normal equilibrium processes in the magma and not of addition to the magma of lime-rich rocks (limestones, etc.).

(417) On some natural and synthetic melilites. A. F. Buddington. Am. J. Sci., 3, 35–87. 1922.

Over 100 synthetic crystalline mixtures of $2CaO.MgO.2SiO_2$, $2CaO.Al_2O_3.SiO_2$, and $3RO.R_2O_3.3SiO_2$ compounds were prepared from appropriate glasses at temperatures above 1000° (the approximate lower limit of experiments); and their homogeneity, the optical characters of those forming homogeneous mixtures and of the dominant phase of some of those forming inhomogeneous mixtures and the temperatures of complete melting were determined.

The compounds $2CaO.MgO.2SiO_2$ and $2CaO.Al_2O_3.SiO_2$ have previously been shown to form a complete series of solid solutions at the solidus and are here shown to agree very closely in their properties with the akermanite-gehlenite series of minerals.

In certain homogeneous solid solutions with the other compounds at certain temperatures, $3CaO.Al_2O_3.3SiO_2$ is shown to have the properties of a negative, uniaxial, moderately birefringent, crystalline compound.

Mixtures of $2CaO.MgO.2SiO_2$, $2CaO.Al_2O_3.SiO_2$, and a third constituent consisting of a mixture of 90 per cent $3CaO.Al_2O_3.3SiO_2$+10 per cent $3Na_2O.Al_2O_3.3SiO_2$ form a complete series of solid solutions, except for a trace of inhomogeneity in some preparations high in $2CaO.MgO.2SiO_2$. Mixtures of these compounds yield crystallized products essentially similar in composition and properties to the minerals of the humboldtilite series, varietal members of the melilite group relatively poor in ferric iron.

The humboldtilites are interpreted as essentially isomorphous mixtures of positive uniaxial akermanite ($2CaO.MgO.2SiO_2$) and a negative, tetragonal, uniaxial, moderately birefringent form of $3CaO.Al_2O_3.3SiO_2$ with minor amounts of gehlenite, a ferrous iron compound, and $3RO.R_2O_3.3SiO_2$ compounds. The compositions of the humboldtilites lie in a zone which exhibits the lowest temperatures of complete melting for the components involved.

Mixtures of $3CaO.Fe_2O_3.3SiO_2$, $2CaO.MgO.2SiO_2$, $3Na_2O.Al_2O_3.3SiO_2$, $2CaO.Al_2O_3.SiO_2$, and $3CaO.Al_2O_3.3SiO_2$, similar in composition to some of the melilites rich in ferric iron, were studied, and the properties of the crystalline material were found to be quite different from those of natural minerals of similar composition.

The natural melilites rich in ferric iron probably form at temperatures lower than those of the present experiments, since some of such melilites investigated decompose or invert at temperatures at least as low as 850°.

Three new analyses of humboldtilites and one of ferric-iron-rich melilite, by Dr. H. S. Washington, are given. The ferric-iron-rich melilite differs from any hitherto analyzed.

This study serves to emphasize the great complexity of this group of minerals and the necessity for further data on their composition and properties and for further experiments in synthesis. The extent to which such known and hypothetical compounds as $3MgO.Al_2O_3.3SiO_2$, $3FeO.Al_2O_3.3SiO_2$, $3K_2O.Al_2O_3.3SiO_2$, $2CaO.FeO.2SiO_2$, $2CaO.Fe_2O_3.SiO_2$, etc., may enter into the melilite minerals, and their corresponding effect, are yet to be studied.

(428) A furnace temperature regulator. Howard S. Roberts. J. Wash. Acad. Sci., 11, 401–409. 1921.

This temperature regulator is a modification of the regulator described by White and Adams (Phys. Rev., 14, 44–48, 1919). The specially made relay in the air apparatus is replaced by stock apparatus which is equally effective and removes the tendency in their apparatus to bring about slow, cyclic variations in the temperature of the furnace. An attachment for the regulator is described, by means of which the temperature of the furnace may be raised or lowered at a nearly linear rate. This is of use in determining melting-points, transition-points, etc.

(430) The granites of Washington, D. C. Henry S. Washington. J. Wash. Acad. Sci., 11, 459–470. 1921.

The granites of the District of Columbia occur in two long belts that extend northwest from near Georgetown. They are intrusive into Archean gneisses. There are two kinds of granite. The most abundant is a biotite granite, which is well exposed in quarries along Connecticut Avenue and along Broad Branch. The spur on which the Geophysical Laboratory stands is composed of this granite. The silica percentage of the biotite granite varies from 67.5 to 69.0. It contains a little oligoclase, scarcely any muscovite, and considerable secondary epidote, but neither hornblende nor allanite. The second kind is a muscovite-biotite granite, which is like the other, but contains about as much muscovite as biotite and has about 72 per cent of silica. Both kinds of granite are more or less foliated and their component minerals are much crushed, effects due to pressure.

Five new chemical analyses show their characters and indicate that the granites are closely related to the less abundant diorites of the District. There seems to be some evidence of magmatic differentiation in the intruded igneous mass, in the sense that it is less silicic and more femic toward the borders. The igneous rocks of the District have been little studied, but a complete study of the geology and petrology of the District is highly desirable.

(431) The distribution of population: A constructive problem. M. Aurousseau. Geogr. Rev., 11, 563–592. 1921.

The rapid rate of increase of the world's population, especially of the white races, is a matter of concern for geography and demands considerable extension of the present methods of study. The nature of the geographical problem is here outlined, and a survey method of assessing the capacity of a given region, the capacity being represented quantitatively as the expansion ratio of the region, is evolved. It is maintained that a method of this kind is the only means of obtaining an exact knowledge of the measure of the human occupation of the habitable lands of the globe and of their resources.

As a preliminary to the determination of the expansion ratio, the existing data which are relevant to the matter are reviewed, with an attempt to systematize them. Urban groups, semiurban groups, and rural groups are considered in some detail, and the broader principles underlying their evolution and distribution have been studied. The region of occupation is next considered, and among the numerous "natural regions" of current geography four classes of regions of different status are distinguished. Cartographic methods are discussed, and examples of the mapping of natural districts and of power mapping are given. It is concluded that the expansion ratios of regions of prolonged occupation, where the grouping of population has adjusted itself to geographical conditions, may be determined on the basis of the existing data, and that, if the subject be developed, a survey method of determination is practicable for any region.

(432) Obsidian from Copan and Chichen Itza. Henry S. Washington. J. Wash. Acad. Sci., 11, 481–487. 1921.

Some Maya cores of obsidian brought back from Copan by Dr. Morley were studied. They are of typical black obsidian, and much like obsidians along the zone of comagmatic igneous rocks that extends along the Rocky Mountains and down the Andes.

A bead of obsidian was examined which came from a *cenote* at the Maya city of Chichen Itza, one of many objects thrown into it as sacrificial offerings. This collection is now in the Peabody Museum and the numerous jades are now under investigation. Chemical analysis of the obsidian bead shows that it is of a very peculiar composition, being high in silica and soda but very low in alumina. The obsidian is much like pantellerites of Italian volcanoes. The result was quite unexpected and is of interest, as it points to the existence of an occurrence of such highly sodic lavas at some point in southern Mexico or northern Central America which is as yet unknown. The occurrence of this rock type emphasizes the need for fuller study of the igneous rocks of Mexico and Central America, about which little is known.

The refractive indices of the two obsidians were determined by Dr. H. E. Merwin. They conform to the general rule observed by Merwin and the author in the study of other obsidians at Lipari, Milos, and elsewhere.

(433) Note on the dissociation of ferric oxide dissolved in glass and its relation to the color of iron-bearing glasses. J. C. Hostetter and H. S. Roberts. J. Am. Ceram. Soc., 4, 927–938. 1921. (Papers on Optical Glass, No. 39.)

Data presented here show that ferric oxide partly dissociates on heating in air, giving off oxygen and forming a corresponding amount of ferrous oxide. The formation of this lower state of oxidation takes place under what are ordinarily considered oxidizing conditions and is to be carefully distinguished from reduction by such gases as hydrogen and carbon monoxide. It is also shown by analyses and color studies that ferric oxide dissolved in glass dissociates in a similar manner, forming ferrous iron, under oxidizing conditions. The degree of dissociation is dependent upon the composition of the glass and probably varies over a wide range as the ratio of alkalies and other constituents of the glass are changed. The data given are insufficient to warrant sweeping conclusions, but further studies along the lines indicated may explain certain observations on color and absorption in relation to chemical composition in iron-bearing glasses.

(434) The lavas of the Hawaiian volcanoes. Henry S. Washington. Hawaiian Annual for 1922, pp. 39–49.

The paper points out briefly some of the characters of the lavas, what they mean and what they may teach as to the constitution of the earth, especially from the chemical side. The paper is written in "popular" style.

(435) A mathematical note on the annealing of glass. E. D. Williamson. J. Wash. Acad. Sci., 12, 1–6. 1922. (Papers on Optical Glass, No. 41.)

From the equations representing the results of experimental work, previously described, the most favorable conditions for annealing a given piece of glass are deduced. Formulas are found which, used in conjunction with tables of the elastic and annealing constants of the glass, show at what temperature to hold the glass, how long to hold it at that temperature, and how rapidly to cool it in order to get any degree of fineness of annealing in the leas possible time. Examples are solved to illustrate the processes.

(436) Augite of Haleakala, Maui, Hawaiian Islands. Henry S. Washington and H. E. Merwin. Am. J. Sci., 3, 117–122. 1922.

The optical and chemical data of a typical augite of an Hawaiian lava are given, this being the first analysis made of an Hawaiian augite. It closely resembles augites from other basalts and is composed chiefly of diopside and hedenbergite, with a little acmite and alumina. The authors reject the view of the existence of Tschermak's molecule, as well as those of Boeke and Zambonini, to account for the presence of alumina in such augites, and assume that the alumina and ferric oxide are present as such in solid solution with the pyroxene molecules. The bearing of an outer film that is high in ferric oxide is briefly discussed.

(437) The crystal structure of ammonium chloroplatinate. Ralph W. G. Wyckoff and Eugen Posnjak. J. Am. Chem. Soc., 43, 2292–2309. 1921.

Crystals of ammonium chloroplatinate ($(NH_4)_2PtCl_6$) probably have a structure which is analogous to that commonly assumed for fluorspar if $PtCl_6$

groups replace the calcium atoms and if NH_4 groups are introduced in place of the fluorine atoms. This determination was made by and serves as an illustration of the general method (previously discussed) for the study of the structure of crystals which is based upon the theory of space-groups. Except in attempting to place the chlorine atoms with accuracy, when it was assumed that atoms scatter X-rays in an amount which is roughly proportional to their atomic numbers and that in a lattice arrangement of atoms the intensities of reflection follow qualitatively the order of $1/(h^2+k^2+l^2)$, the only assumption made that is not required in the ordinary determination of the wavelength of X-rays from a reflection spectrum was that the four hydrogen atoms of the ammonium radical are exactly alike.

(438) The jade of the Tuxtla statuette. Henry S. Washington. Proc. U. S. Nat. Mus., vol. 60, art. 14. 1922.

This "jade" statuette, which is now in the U. S. National Museum, is a work of early Mayan art and is the earliest dated object of American art (98 B. C.). The material was studied chemically by the author and optically by H. E. Merwin and the density was determined by L. H. Adams. It is shown to be a diopside-jadeite, that is, an equimolecular mixture of the molecules of diopside and soda jadeite, the mixture being a rather unusual variety of jadeite. It is also shown that most of the Mexican and Central American jadeites are more or less of this variety and that they differ in this respect from the jadeites of southeastern Asia (Burma and Tibet). Further study of the American jadeites is contemplated.

(439) The development of pressure in magmas as a result of crystallization. George W. Morey. J. Wash. Acad. Sci., 12, 219–230. 1922.

It has been shown that when a system composed of volatile and non-volatile components, such as water and KNO_3, is cooled, crystallization will take place at a temperature lower than the freezing-point of the pure non-volatile salt by an amount corresponding to the amount of volatile material present, and that the corresponding three-phase pressure increases rapidly as the temperature is lowered from the melting-point of the salt. This increase is rapid, whether measured in terms of the decrease in temperature of the three-phase equilibrium or in terms of the content of volatile material in the solution. From the latter fact it follows that in systems of the type of magmas in which the non-volatile material is composed of such material as the silicates, and in which the pressure required to retain any considerable proportion of water in solution must be large, a comparatively small amount of crystallization will result in a large increase in pressure. When a magma containing water cools, with consequent crystallization and development of high pressure, under an incompetent crust, a release of pressure will take place, which may be catastrophic in violence or take the form of a succession of mildly explosive outbursts. In case the magma cools under a competent crust, the pressure will rise to a maximum and then decrease, probably without at any time showing critical phenomena.

(440) Chemical aspects of volcanism, with a collection of the analyses of volcanic gases. E. T. Allen. J. Franklin Inst., 193, 29–80. 1922.

The original volcano gases can be traced back to the igneous rocks. Water is probably the most important of the gases. The original volcanic gases are generally changed in composition by the time they reach the point of collection; in some cases they probably lose a portion of the strong acid gases; in most cases they become diluted by steam from surface water and by the atmospheric gases.

In some volcanic emanations the relations between the inert gases point to an atmospheric origin for these particular constituents; in others the inert constituents must either be of deep-seated origin or their original atmospheric relation has been changed by selective solubility in the magma. Deville's laws respecting the variation in the composition of volcanic gases with the distance from an eruptive center or with passing time are not supported by the great body of evidence.

There is evidence to show that a more or less abrupt evolution of gas from the magma occurs during crystallization, but it needs further support.

Chemical energy from shifting equilibria may have a considerable influence in prolonging the life of an eruption, but not in initiating or rejuvenating volcanic activity. Surface combustion in particular instances is probably an important factor in keeping up temperature. Secondary volcanic explosions of great violence are undoubtedly produced by the access of surface water to hot volcanic ejecta. Some primary explosions are probably of the same character; others, according to the best evidence, are the result of pressure from magmatic gases, not the result of chemical action.

(441) The crystal structures of the cuprous halides. Ralph W. G. Wyckoff and Eugen Posnjak. J. Am. Chem. Soc., 44, 30–36. 1922.

This determination of crystal structure outlines the manner of application of the general method of study, based upon the theory of space-groups, to cubic compounds of the type RX (where R and X are atoms of the same valence) when all of the diffraction data are furnished by a study of the powder photograph from the crystal.

Cuprous chloride, cuprous bromide, and cuprous iodide all have the zinc-sulphide arrangement of their atoms in crystals. The lengths of the sides of the unit cubes in the three cases are 5.49, 5.82, and 6.10 A. U.

(442) Two corrections to mineral data. N. L. Bowen. Am. Mineralogist, 7, 64–66. 1922.

The material from Vesuvius, which has been described as a mineral species and named rivaite by Zambonini, is found to be a piece of ordinary cobalt glass that has been partially devitrified by the heat from the volcanic material with which it is associated. It now consists of prisms of wollastonite embedded in glass and can not be regarded as a mineral species. The so-called reaumurite from Mont Pelée is probably identical.

The optic axial angle (2V) of monticellite from Magnet Cove is given in all textbooks as 37° 31′. This is really the value of V as originally determined by Penfield and Forbes. With this knowledge that the optic axial angle of monticellite is large, it is possible to identify as monticellite the unknown "mineral A" of Larsen and Foshag.

(443) The chemistry of the Pacific volcanoes: The limitations of our knowledge. Henry S. Washington. Proc. Pan-Pacific Scientific Conference, 1920 (Spec. Pub. Bishop Museum, No. 7), pp. 325–345. 1921.

The paper gives a résumé of our knowledge of the chemistry of the volcanic rocks of the Pacific Basin. The volcanoes are referred to two main groups: (1) The Circum-Pacific volcanoes are continental and encircle the ocean from the southern end of South America, through Alaska and Japan, as far as New Zealand. Their lavas are very constant in chemical composition, average high in silica, and are not markedly alkalic. (2) The Intro-Pacific volcanoes are those which occur on the islands scattered through the ocean. They are dominantly basaltic in character, but there are many decidedly alkalic types. It is shown that our knowledge of the whole region generally is very meager; thus we have only about 60 analyses to represent the long line of gigantic Andean volcanoes and only about 130 to represent the very numerous Intro-Pacific volcanoes. Only 46 analyses of the lavas of the Hawaiian Islands have been published so far and of these only 27 are good.

The need of more intense and cooperative investigation is urged and some suggestions are made for the practical collection of specimens and their study.

(444) Remarks on volcanoes. Henry S. Washington. Proc. Pan-Pacific Scientific Conference, 1920 (Spec. Pub. Bishop Museum, No. 7), pp. 361–368. 1921.

A record of informal remarks at the conference.

(445) The thermel. Walter P. White. Science, 55, 617–618. 1922.

A single short name for the thermoelectric thermometer is desirable, since it is inconvenient to call interchangeable instruments of identical use by different names, such as thermocouple and thermopile, depending merely on the number of their parts. The word thermoelement has been used to give this single name, but it is somewhat objectionable and has been so treated as to create considerable confusion. The fact that it has been quite generally used seems to indicate that a single term for the thermoelectric thermometer is welcome. The word *thermel* is now suggested as a short and unequivocal word to take the place of thermoelement as more recently used. Logically, it is an abbreviation of both thermoelement and thermoelectric thermometer, and in meaning it is simply synonymous with thermoelectric thermometer.

(446) Change of the physical properties of materials with pressure. E. D. Williamson. J. Franklin Inst., 193, 491–513. 1922.

It is only in recent years that it has been possible to make accurate measurements of the physical properties of materials under high pressures. The volume of results obtained is, however, already quite considerable and deductions of value have been made for both applied and pure science.

This address presents a collection of the most recent results showing the effect of pressure on the following properties: (1) electrical resistance of solids, liquids, and solutions; (2) compressibility of liquids and solids, including a number of metals and a few rocks; (3) viscosity of a number of lubricating oils. The effect upon electrical theory of the results obtained is discussed briefly in reference to the work of P. W. Bridgman, and possible applications of the study of the other properties are indicated. The light shed by earthquake observation on questions of the elastic properties of rocks is also discussed and possible deductions pointed out.

(447) On contact phenomena between gneiss and limestone in western Massachusetts. Pentti Eskola. J. Geol., 30, 265–294. 1922.

Within the area of the igneous Becket granite gneiss in western Massachusetts there occur several tilted layers of crystalline limestone, called Coles Brook limestone, older than the gneiss and metamorphosed by its contact influence. In the vicinity of the limestone the gneiss contains considerable quantities of lime-bearing silicates, especially of clinopyroxene (diopside-hedenbergite) and titanite, apparently the result of assimilation of limestone by the gneiss magma.

The gneiss is markedly banded, with alternating darker and lighter bands. It was found, by determining the refractive indices of the chief mafic minerals, biotite, clino-amphibole, and clino-pyroxene, that the amount of their magnesia compounds in proportion to their ferrous compounds increases with the total quantity of the mafic constituents. At the same time the amount of anorthite in the plagioclase increases. Thus, the dark bands behave like the earliest separated rocks in a differentiation series. Some differentiation by crystallization really seems to have taken place after the assimilation. In certain places, however, and especially at the immediate contacts against the limestone, the actual composition of the gneiss appears to be a direct result of assimilation and no correspondence between Fe : Mg ratio and "basicity" exists. The distribution of magnesia and ferrous oxide among the different mafic minerals was found to show a certain regularity, the mica always being richest and the clinopyroxene poorest in the iron compound. The variation of the "Fe quotient" is believed to offer an important characteristic of crystalline rocks, though at present little understood.

When silica-bearing limestones are subjected to metamorphism, reactions occur between the carbonates and silica, and silicates of lime and magnesia are formed. The temperature of reaction varies with pressure and is different for different minerals formed, as pointed out by V. M. Goldschmidt. The writer's earlier investigations have established that, among the common accessory silicates in limestones, wollastonite requires the highest temperatures to form, and diopside and tremolite successively lower. At still lower temperatures silica in the form of quartz remains uncombined. Thus we may distinguish the following types of metamorphic limestone: wollastonite limestone, diopside limestone, tremolite limestone, and quartz limestone. These types may be used, under certain conditions, as a geologic thermometer, and it is hoped that the equilibrium curves of the different silicates with the carbonates may soon be determined experimentally.

The limestones of western Massachusetts were found to represent all the above-named types excepting the wollastonite limestone. Their mode of occurrence harmonizes with the writer's earlier experience, diopside limestone occurring at the immediate contacts of the gneiss, and tremolite limestone and quartz limestone successively farther away.

A review of the writer's experience from limestone-bearing regions where intrusive granites occur seems to prove that such phenomena of assimilation of limestone as those observed in western Massachusetts are not at all of regular occurrence. Preferably they seem to occur in those regions where gneiss magmas have been intruded in connection with mountain folding, thus in all probability being dependent on the mechanical conditions. It appears, also, that assimilation does not require very high temperatures, being a common phenomenon in granite pegmatite cutting limestones.

(448) Nephrite celt from Bahia, Brazil. Henry S. Washington. Pan-American Geologist, 37, 198–202. 1922.

A small celt of nephrite from the Paraguassu River, in Bahia, is described. Nephrite objects from Brazil are very rarely seen outside of that country. The nephrite is of the typical color, luster, toughness, and micro-structure. It is composed entirely of a pale greenish tremolite in very fine fibers. The optical characters, density, and a chemical analysis are given. It is compared with other nephrites from Brazil. It is suggested that one of these, of unusual chemical composition, may be a mixture of albite and enstatite-diopside, analogous to the mixture of albite and diopside-jadeite found in Central America and Mexico.

(449) The crystallographic and atomic symmetries of ammonium chloride. Ralph W. G. Wyckoff. Am. J. Sci., 3, 177–183. 1922.

It is shown that not only is the symmetry of the structure that has been assigned to ammonium chloride in conflict with its observed symmetry, but that there is no other possible structure which will possess the requisite symmetry. As a result the necessity of further study of the crystallography of this salt is urged.

(450) The crystal structure of silver oxide (Ag_2O). Ralph W. G. Wyckoff. Am. J. Sci., 3, 184–188. 1922.

Employing the method of powders, it is shown that silver oxide has the same structure as that assigned to cuprous oxide. The length of the side of the unit cube is determined to be 4.76^8 A. U.

(451) The reaction principle in petrogenesis. N. L. Bowen. J. Geol., 30, 177–198. 1922.

Petrogenic theory has passed beyond the stage where the conception of eutectics can longer be regarded as of any considerable service. Experimental investigations and the study of the rocks themselves in the light of such investigations have made it clear that the eutectic relation is unimportant, but that another relation between liquid and crystal phases, here called the reaction relation, is of fundamental significance. The ordinary solid solution series, such as the plagioclases, may be regarded as a *continuous reaction series*, because during crystallization each member is produced from an earlier member by reaction with the liquid, the variation of composition being continuous. There are also *discontinuous reaction series* exhibiting related characters but with discontinuous changes of composition. The series olivine-pyroxene-amphibole-mica is a prominent example among the rock-forming minerals.

On the basis of these considerations the minerals making up the rocks of an igneous sequence can be arranged as reaction series, and it is the existence of such series that controls the crystallization and differentiation of the rocks of the sequence. Even the graphic structure, often regarded as a eutectic structure, is probably to be considered the result of reaction between the phases.

(452) The crystal structures of the alkali halides. I. Ralph W. G. Wyckoff. J. Wash. Acad. Sci., 11, 429–434. 1921. II. Eugen Posnjak and Ralph W. G. Wyckoff. Ibid, 12, 248–251. 1922.

These papers furnish an account of the study of the crystal structure of some of the alkali halides and, with the exception of rubidium fluoride, complete our knowledge of the structures of these compounds. The crystal-structure data were obtained from the study of X-ray photographs of powders. Except cæsium chloride, bromide, and iodide, which have a body-centered structure, all the other alkali halides have the sodium-chloride arrangement.

(453) The melting of potash feldspar. G. W. Morey and N. L. Bowen. Am. J. Sci., 4, 1–21. 1922.

A pure synthetic orthoclase was prepared by crystallizing glass of the composition $KAlSi_3O_8$ in a bomb with water-vapor. This material is particularly suitable for the determination of the melting-point of pure orthoclase and was used for that purpose. The temperature ordinarily given as the melting-point of orthoclase is about 1200° and has been determined on natural crystals. When our artificial crystals were held at 1200° for a week, they gave a product which had the appearance of a glass, *megascopically*, but which, examined under the microscope, showed a structure described as a very fine cross-lining. At higher temperatures this structure became more distinct, taking the successive forms shown in figure 1, and finally becoming typical leucite crystals. The point at about 1200° is therefore not the true melting-point of orthoclase, but is the temperature at which it melts incongruently, breaking up into liquid and leucite. The exact temperature of this decomposition we have determined as somewhat lower than 1200°, namely, about 1170°. The temperature of final disappearance of leucite is about 1530°, so that the interval of incongruent melting is remarkably large, viz, 360°. Three natural potash feldspars, microcline from North Carolina, sanidine from Laacher See, and adularia from St. Gotthard, show the same kind of behavior, though in these the upper limit of melting (disappearance of leucite) is lowered somewhat through the presence of foreign matter.

This incongruent melting of orthoclase is of particular importance in petrogenic theory, because it shows plainly how by fractional crystallization a homogeneous liquid could form a differentiated mass consisting of orthoclase and leucite in one part and of orthoclase and free silica in another. It shows, too, that leucite can form from a liquid containing an adequate amount of silica to form orthoclase and that a mass may have leucite as early crystals (phenocrysts) together with free silica as late crystals (groundmass). These considerations explain the occurrence of such a rock as the leucite-granite porphyry of Brazil and such a differentiated mass as the syenite laccolith at Loch Borolan, Scotland. It is to be noted that both these occurrences show pseudo-leucites, formed secondarily after leucite, and consisting, as do the leucites of intrusive rocks in general, of an intergrowth of orthoclase and nephelite (or secondary products after nephelite). This regular behavior of leucite in breaking up into orthoclase and nephelite suggests that the early separation of leucite, with a subsequent change of that nature, may afford a key to the origin of many nephelite rocks as well as leucite rocks.

(454) Augite and hornblende from Kilimanjaro. Henry S. Washington and H. E. Merwin. Am. Mineralogist, 7, 121–125. 1922.

The chemical and optical characteristics found for the augite from Kilimanjaro are almost identical with those of several augites of high diopside-content from rocks markedly different chemically. Similar comparisons of the hornblende can not be made on account of the lack and questionable character of data.

(455) The application of thermodynamics to heterogeneous equilibria. George W. Morey. J. Franklin Inst., 194, 425–484. 1922.

The underlying purpose of the four lectures included in this paper was to present, in as simple a form as possible, the fundamental features of that portion of Gibbs's great paper, "Equilibrium of Heterogeneous Substances," which lead up to and are essential to the development of his equation 97. As is emphasized throughout, this equation is a powerful weapon for attacking the problem of equilibria between phases, and affords a more direct and simple, as well as a far more potent, attack than does the usual statement of the phase rule, which is but an incidental qualitative deduction from equation 97. By the detailed application of this equation, problems of heterogeneous equilibria may be solved completely if the entropy and volume changes are known in their entirety. But more than this, by the application of this equation, and such a general knowledge of entropy and volume differences as are involved in the knowledge that a vapor phase has a greater entropy and volume than the liquid phase with which it is in equilibrium, or that the high-temperature modification of a phase has a greater entropy than the low-temperature modification, it is possible to predict, with an approach to quantitative accuracy, the behavior of the system when subjected to changes in pressure, temperature, and composition. Furthermore, this thermodynamic method is not limited in its application to two or three component systems, but can be extended readily to include any desired number of components.

A sharp line must be drawn between those relations which are derived from the two laws of thermodynamics without the aid of further assumptions and those whose derivation involves not only the thermodynamic laws proper, but also further assumptions extraneous to thermodynamics. To this latter clan belong the dilute-solution approximations. In dealing with dilute solutions it is usual to assume some relation between composition and thermodynamic properties which will enable a divariant equilibrium such as that between ice and a dilute salt solution, to be treated as a univariant equilibrium. It was shown by Gibbs that when the amount of one component approaches zero, such a relation becomes possible, and he indicated the form the relation would take. Making certain explicit assumptions, he further identified the constant value which the rate of change of the potential of water with addition of salt approaches as the amount of salt approaches zero, with the gas constant for one gram of the solute. Making these assumptions, the derivation of the ordinary dilute solution laws is easy, and this method of derivation has the advantage of confronting us squarely with the assumptions involved in these dilute-solution approximations.

(456) Realization of absolute scale of temperature. Arthur L. Day and Robert B. Sosman. Dictionary of Applied Physics (R. T. Glazebrook, Editor), vol. 1, pp. 836–871. 1922.

This paper is a comprehensive outline and review of the thermodynamic scale of temperature and its realization by experimental means. The subject is treated under the following heads: Temperature scales; forms of gas-thermometers; basic experimental results with gas-thermometers; means of comparison of gas-thermometers with secondary standards; comparison of gas thermometers with secondary standards in the range of 0° to 100°; −273° to 0°; 100° to 500°; 500° to 1600°; the sources of error in gas thermometry.

(457) Glass technology. George W. Morey. J. Ind. Eng. Chem., 14, 823–824. 1922.

A review of the progress of glass technology during the preceding two years.

(458) The use of minerals as radio-detectors. H. S. Roberts and L. H. Adams. Am. Mineralogist, 7, 131–136. 1922.

This paper, which was written at the request of the editor of the American Mineralogist, contains a brief exposition of the operation of the crystal detector, a list of the substances most commonly used, together with a tentative explanation of their action. It is followed by a list of the more important references to periodical literature on the subject.

(459) The behavior of inclusions in igneous magmas. N. L. Bowen. J. Geol., 30, 513–570. 1922.

The observed effects of magmas upon inclusions are usually to be referred to an action other than the direct solution of inclusions in superheated magma. An application of the conception of the reaction series to the solution of the problem affords an explanation of the effects of magmas, even though saturated. Certain principles governing the effects of liquid upon inclusions belonging to reaction series can be developed by studying the equilibrium diagrams of systems involving both continuous and discontinuous reaction series. In this manner it can be decided definitely that a liquid saturated with a certain member of a reaction series is effectively supersaturated with all preceding members of that series. It can not dissolve such members, but can only react with them to convert them into the members with which it is saturated. The reaction is not a simple subtraction from the liquid of the material necessary for this transformation, but some precipitation from the liquid itself is involved and the liquid ordinarily maintains its position on the same saturation surface. The products of crystallization from the liquid and the possible course of fractional crystallization are thus unaffected.

On the other hand, a liquid saturated with a certain member of a reaction series is unsaturated with all subsequent members of the series. Inclusions consisting of these later members can become a part of the liquid by a sort of reactive solution, the heat of solution of inclusions being supplied by the precipitation of their heat equivalent of the member of the series with which the liquid is saturated. It should be noted that the material that can by this reactive process become a part of the liquid must consist of a later member of the reaction series, that is, must be material toward which the liquid could pass spontaneously by fractional crystallization. The net effect upon the liquid is, then, to push it onward upon its normal course.

The products of crystallization of subalkaline magmas can be arranged as reaction series. The action of magmas upon foreign inclusions of igneous origin may be deduced from this arrangement of the crystalline products as series by application of the principles developed from the above study of simple systems. Thus we find that a granitic magma saturated with biotite can not dissolve olivine, pyroxene, or amphibole, but can only react with them to convert them into biotite, the phase with which it is saturated; or, stated more generally, no saturated magma can dissolve inclusions consisting of minerals belonging to an earlier stage of the reaction series (usually more basic).

Saturated basic magma, on the other hand, will react with inclusions belonging to a later stage of the reaction series (more acidic), the reaction being of such a nature that the inclusions become a part of the liquid by precipitating their heat equivalent of the phases with which the magma is saturated (basic minerals). The inclusions, it should be noted, must be of a composition toward which the liquid could pass spontaneously by fractional crystallization. Thus, saturated basaltic magma can dissolve granitic inclusions by precipitating basic minerals, and the granitic material passing into solution then becomes a contribution to the normal granitic differentiate that may form by fractional crystallization if the conditions are appropriate.

The behavior of inclusions of sedimentary origin is more complicated, since sedimentary material does not belong in the reaction series. A consideration of the extent and nature of the variation of composition possible in the crystalline phases formed from a magma shows that the incorporation of considerable amounts of sedimentary material would ordinarily bring about merely an adjustment in the composition and relative proportions of existing phases. As a result of the non-appearance of new phases, the general course of fractional crystallization is unaffected. In general, the adjustment noted takes place through precipitation of the phases with which the magma is saturated. As an example, it may be stated that the addition of highly aluminous sediments to basic magma should bring about the formation of anorthite and enstatite molecules at the expense of diopside molecules and should therefore cause the precipitation of crystals rich in anorthite and enstatite. Such action may have been important in the formation of many norites. The foreign material becomes a part of the general mass as a result of reaction and precipitation rather than by simple solution.

It may be stated, therefore, that magmas may incorporate considerable quantities of foreign inclusions, both by the method of reactive solution and by reactive precipitation, and such action may have been important in connection with the production of certain individual masses. Thus some norites may have been produced as a result of the reactions discussed above, some granites may have had their mass augmented by reactive solution of granitic inclusions in the magma from which they differentiated, some alkaline rocks may have been formed as a result of the presence of limestone inclusions in the liquid from which they differentiated. All of these actions are, however, an emphasizing of normal processes possible in the absence of foreign matter. It is doubtful whether the presence of foreign matter is essential to the production of any particular type of differentiate.

(460) Isostasy and rock density. Henry S. Washington. Bull. Geol. Soc. Amer., 33, 375–410. 1922.

In this paper, which is an expansion of part of a former one ("The chemistry of the earth's crust," by Henry S. Washington, published in the Journal of the Franklin Institute, vol. 190, pp. 757–815, 1920, reviewed in Year Book No. 20, p. 165), there is presented a study of the relations between the average densities of different areas of igneous rocks and their average altitudes, with the object of correlating these relations with the theory of isostasy. The outcome of the discussion is that the general relation holds good: *the average density of the igneous rocks varies in the opposite sense as the average altitude.* The results of the study, therefore, harmonize with and corroborate the theory of isostasy.

Comagmatic regions, in which the igneous rocks are shown by their similar chemical and mineral characters to be derived from the same magma, are briefly discussed, especially as to their bearing on isostasy, and the distribution of them throughout the United States is described.

The normative method for arriving at the average density of a region is described in detail. This method consists in calculating the norm of the average rock of the region and, from the known densities of the normative minerals, calculating the average density. The average densities of many areas over the globe, including the earth as a whole, the continents and ocean floors, and many countries and states, resulting from these calculations, are given in a table and their relations to the corresponding altitudes are discussed.

The physical method of calculating the average density, which consists in averaging the specific gravities determined by the balance, is discussed and some results are given. It is shown that this method is not capable of yielding such consistent and reliable results for the present purpose as the normative method.

The depth of the "isopiestic level" or "depth of compensation," at which all the various columns of inversely varying densities and heights balance each other or exert the same pressure, is discussed. The depth is calculated from the known average altitudes and the average densities calculated by the normative method, using different sets of areas. It is shown that the normative method is capable of yielding reliable results with proper data, and that the most probable value on this basis for the isopiestic depth is 59 km., which agrees well with Bowie's value of 60 km., arrived at by gravity methods at stations distributed over the United States, but which differs from that of 96 km. derived from mountain stations and accepted by Bowie as the best. It is shown that the former value is probably the more correct.

The correspondence between the distribution of comagmatic regions and areas of positive and negative anomaly in the United Sates is briefly discussed.

(461) The system $Fe_2O_3-SO_3-H_2O$. E. Posnjak and H. E. Merwin. J. Am. Chem. Soc., 44, 1965–1994. 1922.

The system $Fe_2O_3.SO_3.H_2O$ has been studied over the temperature range from 50° to 200°. The following crystalline phases were encountered: Fe_2O_3; $Fe_2O_3.H_2O$; $3Fe_2O_3.4SO_3.9H_2O$; $Fe_2O_3.2SO_3.H_2O$; $Fe_2O_3.2SO_3.5H_2O$; $2Fe_2O_3.5SO_3.17H_2O$; $Fe_2O_3.SO_3$ (2 forms); $Fe_2O_3.3SO_3.6H_2O$; $Fe_2O_3.3SO_3.7H_2O$; $Fe_2O_3.4SO_3.3H_2O$; and $Fe_2O_3.4SO_3.9H_2O$.

The conditions under which these substances are formed, the range of their stability, and their relation to one another, also some of their crystallographic and optical properties, were determined. The data obtained are presented by means of tables, and graphically by means of curves and a solid model.

(462) The average chemical composition of igneous rocks. Frank W. Clarke and Henry S. Washington. Proc. Nat. Acad. Sci., 8, 108–115. 1922.

This paper presents a series of about 50 averages of the chemical composition of the igneous rocks of various countries and continents, together with a final average of the average chemical composition of the igneous rocks of the earth, expressed both in oxides and as elements. In the latter, estimates are made of the order of abundance of many of the rare elements. These averages are to appear with full discussion in a forthcoming Professional Paper of the U. S. Geological Survey by the same authors, entitled "The composition of the earth's crust."

(463) The nephelite syenite and nephelite porphyry of Beemerville, New Jersey. M. Aurousseau and Henry S. Washington. J. Geol., 30, 571–586. 1922.

The scattered contributions to the geology and petrology of the alkalic igneous rocks of northern New Jersey are reviewed in chronological order and a general account of these rocks is given. The large mass of nephelite syenite northwest of Beemerville is described and is interpreted as a lenticular sill or a flat laccolith of foyaite, intruded by a mass of nephelite porphyry (probably a dike) and by a small dike of leucite tinguaite.

New analyses of the nephelite syenite (foyaite) and of the nephelite porphyry are presented and the affinities of these rocks and of leucite tinguaite are discussed. It is concluded that these three rocks are textural and mineralogical variants, without chemical differentiation, of the same magma.

It is shown that the nephelite porphyry is not a sussexite, as formerly supposed, and the status of sussexite as a rock variety is considered, with the conclusion that the name should be retained in its original sense, but that the nephelite porphyry of Beemerville can no longer be regarded as the type of the variety.

The presence of zirconium and the rare earths in the Beemerville rocks has been established, and the wide distribution of these elements in the region east of the Appalachians is briefly discussed.

(464) The determination of the space-group of a cubic crystal. Ralph W. G. Wyckoff. Am. J. Sci., 4, 175–187. 1922.

Criteria which are valid for crystals which have any atoms of appreciable scattering power in general positions are established for determining from studies of Laue photographs the space-group to which a cubic crystal should be assigned. This knowledge is of value to the crystal analyst because it is thus possible to tell how the atoms in many chemically complicated crystals are arranged, even though existing methods are not sufficient to locate these atoms with accuracy, and because an assignment of a crystal to a particular space-group defines completely the positions of all of its elements of symmetry. Many of the space-groups give diffraction effects which are different from those given by any other groups, and hence a method is provided, in the cases of crystals assignable to any of these unique space-groups, of defining completely crystal symmetry without making use of the older methods, such as face development and the like.

(465) Possible causes of the volcanic activity at Lassen Peak. Arthur L. Day. J. Franklin Inst. 194, 569–582. 1922.

An address delivered before the Commonwealth Club of San Francisco on July 21, 1922.

The address contains a brief account of the volcanic outbreak of Lassen Peak which began in 1914 and continued for nearly 4 years. Practically all of the phenomena observed during this period of activity were the direct or indirect results of steam explosions without evidence of temperatures higher than red heat. It is suggested that, inasmuch as Lassen Peak lies in a region of considerable rainfall, the magma beneath the volcano carries a large percentage of water in solution, which is necessarily discharged during crystallization with enormous local increase of pressure. It is believed that this is the only mechanism hitherto studied through which sudden developments of extreme pressure are possible in a cooling system. (See No. 439.)

(471) The analytical expression of the results of the theory of space-groups. Ralph W. G. Wyckoff. Publication No. 318, Carnegie Institution of Washington.

All of the ways in which atoms can be arranged in space so that their aggregate will possess one of the groups of symmetry properties observed in crystals can be obtained from the theory of space-groups. Thus, in giving a knowledge of all possible atomic arrangements in a crystal in advance of detailed experimentation, this theory enters directly into the determination of the structures of crystals through X-ray diffraction effects.

The purpose of this book is to put the results of space-group theory into a form immediately usable to the crystal analyst. As originally stated, the theory concerned itself primarily with the different possible ways of spacially distributing the elements of symmetry characteristic of crystals. For the calculation of the X-ray diffraction effects to be expected from a grouping of atoms, however, the coordinate positions of the atoms contained within a unit cell of the crystal are desired. In the tables which constitute the major portion of this book, the coordinates of the equivalent points (as positions for chemically like atoms) are given for each of the 230 space-groups. Generally equivalent positions are obtained by operating upon *any* point within the unit cell of a space-group by the characteristic elements of symmetry; the special cases arise when the number of equivalent points is reduced through their lying in one or more elements of symmetry. Not only are the general positions stated, but the physically much more important special cases have all been expressed in detail. A complete analytical expression is thus attained in a form directly applicable to processes of crystal-structure determination.

Because a brief account of the nature of the space-groups is not available to English readers, a short discussion precedes the principal tabulations, which, it is hoped, will somewhat fill this gap.

(475) Solubility and decomposition in complex systems. George W. Morey. J. Soc. Glass Technology, 6, 20–29. 1922.

The decomposition by water of glass and ceramic wares is a phenomenon of great practical importance, primarily because the tendency toward such decomposition is one of the factors which sets a limit in certain directions on the compositions which we may employ. In this paper decomposition is discussed from the point of view of the phase rule and illustrated by comparison with the complex systems H_2O-K_2O-CrO_3 and H_2O-K_2O-SiO_2. It is emphasized that the action of water on complex silicate mixtures, whether crystalline or wholly or in part glassy, is one of decomposition; and the results of experiments to determine the relative fitness of such mixtures to withstand the action of water or solutions should not be confused with the results of true solubility determinations. The results obtained by tests as ordinarily carried out represent the rates of decomposition, and because such rates are profoundly affected by experimental conditions great care must be exercised in specifying all of these conditions and in maintaining them constant.

The following papers were published by Dr. R. W. G. Wyckoff, of this Laboratory, while a guest of the Gates Chemical Laboratory of the California Institute of Technology:

The crystal structure of the hexammoniates of the nickel halides. Ralph W. G. Wyckoff. J. Am. Chem. Soc., 44, 1239–1245. 1922. (Contribution from the Gates Chemical Laboratory of the California Institute of Technology, No. 12.)

It has been shown that in the arrangement of their atoms the hexammoniates of nickel chloride, bromide, and iodide are strictly isomorphous with ammonium chloroplatinate. The dimensions of the unit cells for each of these salts and the values of the variable parameters defining the positions of the nitrogen atoms in the chloride and iodide have been estimated.

The composition and crystal structure of nickel nitrate hexammoniate. Ralph W. G. Wyckoff. J. Am. Chem. Soc., 44, 1260–1266. 1922. (Contribution from the Gates Chemical Laboratory of California Institute of Technology, No. 14.)

From X-ray spectrum measurements and space-group reasoning it can be shown that the crystals formed on the addition of ammonia to a solution of nickel nitrate can not have the composition usually ascribed to them. Careful chemical analysis proves them to be $Ni(NO_3)_2.6NH_3$. A study of the Laue photographs of these crystals by the generally applicable methods which use the theory of space-groups indicates that they have a structure similar to that of the previously studied nickel hexammoniate halides with NO_3 groups replacing the halogen atoms and the ammonia groups related to the nickel atoms in the same manner in both compounds. The positions of the atoms of the nitrate groups can not, however, be determined with great accuracy. Both the symmetry characteristics and the diffraction data permit the same kind of displacement of the nitrate-nitrogen atoms as is experienced by the sulphur atoms in pyrite.

The symmetry and crystal structure of zinc bromate hexahydrate, $Zn(BrO_3)_2.6H_2O$. Ralph W. G. Wyckoff. Am. J. Sci., 4, 188–192. 1922. (Contribution from Gates Chemical Laboratory of California Institute of Technology, No. 16.)

From a study of the Laue photographs to which crystals of zinc bromate hexahydrate give rise, it is shown that they must have the symmetry of the space-group T_h^6. Though it is impossible to determine the positions of the atoms in this crystal, such knowledge of the underlying space-group defines uniquely the manner of arrangement of its atoms. The length of the side of the unit cube, which contains 4 chemical molecules, is found to be 10.31 A. U.

On the symmetry and crystal structure of sodium hydrogen acetate, $NaH(C_2H_3O_2)_2$. Ralph W. G. Wyckoff. Am. J. Sci., 4, 193–198. 1922. (Contribution from Gates Chemical Laboratory of California Institute of Technology, No. 17.)

It is shown that the unit cell of sodium hydrogen acetate must contain 24 chemical molecules. The length of the side of this unit cube is found to be 15.98 A. U. The determination of the underlying space-group as probably T_h^7 defines the general manner of the arrangement of the atoms of this crystal, though it is impossible to obtain the positions of these atoms. A graphical method is outlined for identifying the planes causing the secondary spectra upon a reflection spectrum photograph.

The crystal structure of silver molybdate. Ralph W. G. Wyckoff. J. Am. Chem. Soc., 44, 1994–1998. 1922. (Contribution from the Gates Chemical Laboratory of the California Institute of Technology, No. 18.)

Using the generally applicable methods based upon the results of the theory of space-groups and taking the data from reflection spectra and Laue photographs, it is shown that silver molybdate has the same crystal structure as the spinels and magnetite. The length of the side of the unit cube, which contains 8 molecules, is 9.26 A. U.; the parameter defining the position of the oxygen atoms is close to 3/8.

DEPARTMENT OF HISTORICAL RESEARCH.[1]

J. Franklin Jameson, Director.

The following report, the seventeenth annual report submitted by the present Director, covers the period of twelve months extending from September 1, 1921, to August 31, 1922.

In the staff of the Department two changes have occurred during the year reported upon. Miss Shirley Farr, who since January 1, 1920, had rendered excellent service to the Department, chiefly in connection with the editing of the *American Historical Review*, resigned her position after fifteen months' continuance, her resignation taking effect on the first of April. Her place has been filled by the appointment of Miss Mary F. Griffin, of Washington, formerly an editor of publications in the Bureau of the Census, who began service with the Department on the first of May. From December 1, Mrs. Louise F. Pierce has been the stenographer of the Department, taking the place, after an interval, of Miss Louisa F. Washington.

At the time with which the last report concluded, the Director was in England, occupied, as he had been during July and August, with the collecting of materials and the making of arrangements for the proposed volumes of the Correspondence of the British Ministers to the United States. He remained in England till October 8, working upon this task, most of the time in London. A brief visit was made to Bristol, for examination of slave-trade papers in the possession of the Society of Merchant Venturers and in the Hobhouse Collection in the Bristol Public Library, in connection with Miss Donnan's proposed volumes of documents illustrating the history of the slave trade to America. Visits were also made to Cambridge and to Edinburgh, the latter with two objects, the one connected with the papers of Sir Robert Liston, second British minister to the United States, and the other connected with a search in the archives of the General Register House, which Miss Sybil Norman has been carrying on for the Department, toward the making of a list of materials relative to American history which are to be found in that repository. The Director also attended, as a member, a session of the Anglo-American Historical Committee, formed as a result of the Anglo-American Conference of Professors of History held at the University of London in the preceding July.

After leaving London the Director made brief visits to the principal library of Rouen and to the chief archives in Paris, and then proceeded to Spain for a brief reconnaissance of the leading archives, intended to put him in a position to shape more intelligently any subsequent plans for further work of the Department in Spain. He visited the three archives most important in respect of materials for American history, that of Simancas, the Archivo Historico Nacional at Madrid, and the Archivo General de Indias at Seville, where he received every kindness from the respective chief archivists, Señor Don Juan Montero, Señor Don Joaquin Gonzâlez y Fernândez, and Señor Don Pedro Torres Lanzas, and from Miss Irene A. Wright, the friend and adviser of all American workers in Seville. Sailing from Lisbon, he also had an opportunity to examine the principal archive of Portugal, that called the Archivo da Torre do Tombo.

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Another member of the staff, Miss Davenport, has been in London throughout the whole of the year reported upon, working in the British Museum and the Public Record Office. Mr. Leland sailed for France at the end of April, and since then has been occupied with researches in the libraries and archives of Paris, described at a later point in this report.

Several persons outside the regular staff of the Department have during the year given important and valued assistance to its work. In May and June, Professor Marcus W. Jernegan, of the University of Chicago, was in Washington for a brief period of assistance to Dr. Paullin in the completion of those maps in the *Atlas of the Historical Geography of the United States* which are to illustrate educational and religious history. Professor John S. Bassett, of Smith College, devoted most of September 1921, part of June 1922, and nearly all of July and August to the continuance of his editorial work upon the Correspondence of Andrew Jackson, working partly in Washington and partly in Northampton. Miss Jane Boyd continued the work of transcription from September to April, and was succeeded in it by Miss Ruth McDuffie, who brought it to a completion by the end of July. Professor W. J. Seelye assisted both in collation.

Others outside the regular staff who assisted the work of the Department during the year were Miss Elizabeth Donnan, formerly a member of the Department, now an assistant professor in Wellesley College; Mrs. N. M. Miller Surrey, of New York City; Mrs. R. C. H. Catterall; Mr. David M. Matteson, of Cambridge; Professor Herbert C. Bell, of Bowdoin College; Miss Louise Phelps Kellogg, of Madison, Wisconsin; Mr. Abel Doysié, of Paris; Miss Ruth A. Fisher, Miss Lillian M. Penson, Miss Isobel D. Thornley, and Miss B. Eliott Lockhart, of London.

As in previous years, acknowledgment is cordially made of the favors constantly shown to the Department, with the greatest liberality, by the officials of the Library of Congress, and especially by Dr. Herbert Putnam, the librarian; by Mr. A. P. C. Griffin, chief assistant librarian; by Mr. Charles Moore, chief of the Manuscripts Division, and by Mr. P. Lee Phillips, chief of the Map Division. Grateful recognition is also made of the courtesy shown by the New York Public Library and that of Harvard University in facilitating the work of Mrs. Surrey and Miss Donnan, respectively; by the authorities of the British Museum and the Public Record Office in aiding that of Miss Davenport, Miss Fisher, and others; and by librarians and archivists in Paris and Havre, especially the librarian of the American Library in Paris, Mr. W. Dawson Johnston.

REPORTS, AIDS, AND GUIDES.

The *Guide to Materials for American History in Paris Archives and Libraries*, upon which Mr. Leland has long been engaged, was advanced during the autumn and winter to such a point that, in April, he was ready to go again to Paris to bring it to completion, by filling whatever gaps were left in his notes when his work there was interrupted by the advent of war in 1914, and by taking note of all the materials which since that date have come into any of the archives or libraries of Paris.

Since arriving in Paris, on May 7, Mr. Leland has occupied himself chiefly with manuscripts in the Bibliothèque Nationale relating to American history, especially in the collection entitled Nouvelles Acquisitions, Collection Arnoul, being papers of Nicolas and Pierre Arnoul, intendants of the marine at Toulon and Rochefort under Louis XIV, and in that called Mélanges de Colbert, containing papers relating to the colonial administration of that statesman, during the same reign. He has also made a special examination of the very extensive collection of American sketches in the Museum of Natural History at Havre, made in America in the period from 1819 to 1839 by the French naturalist Charles Alexandre Lesueur. Another expedition out of Paris has been devoted to an examination of the papers, chiefly papers of the Compagnie des Indes, preserved in the archives of the office of the marine at Lorient. While in principle Mr. Leland's work is confined to the archives and libraries of Paris, and search of the archives of the departments and other outlying collections is not contemplated, the papers concerning French America preserved at Lorient are so closely related to those in the archives of the Ministries of the Marine and Colonies that it has seemed logical to include them in this inventory.

Of the three volumes of which Mr. Leland's Guide will be composed, it is his intention to complete first the volume relating to manuscripts in the libraries of Paris, concerning America; then the second volume, relating chiefly to the American materials in the Archives Nationales; then the third, relating to materials in the archives of the Ministry of Foreign Affairs and other ministries which have not thus far deposited their papers in the Archives Nationales.

As in previous years, Mr. Leland has received valuable aid from Mr. Abel Doysié, whose knowledge of the materials for American history in Paris archives and libraries is extraordinary. Mr. Doysié also rendered signal assistance to the Director during his brief visit to Paris archives in the October preceding, finished in the autumn his work on the archives of the Service Hydrographique, and labored in the winter on section C^{11} of those of the Colonies. His help to Mr. Leland has lain chiefly in the field of French colonial finance and papers relating to that subject.

The work upon which Mrs. Surrey has been engaged, the making of a catalogue of documents in Paris archives relating to the history of the Mississippi Valley, is in practice an adjunct to the work of Mr. Leland and Mr. Doysié just reported upon, though it has a separate history and origin, which have been described in previous reports. Her work during the past year, continued from September 1 to July 1, has in one respect differed from that of previous years, for whereas much of it has been based on the notes taken in Paris archives and libraries before the war by Mr. Doysié and other persons who were then assisting Mr. Leland, another part, perhaps as great, has been based on full-length transcripts of Paris documents, acquired during the intervening years, mainly under Mr. Leland's supervision, by the Library of Congress. Independent examination of these transcripts has enabled Mrs. Surrey to improve her calendar by avoiding some imperfections found in the older portion of the notes taken in Paris. Another portion of the American material in the Archives Nationales for which our older notes stand especially in need of revision is that in what is called Series B in the archives of the Ministry of the Colonies. Going to Europe for a summer's vacation at her own expense, Mrs. Surrey has at much personal sacrifice resolved to spend the autumn in Paris in the work of perfecting her calendar of the papers relating to Louisiana, Canada, and other colonies, in that series. She reached Paris, and began work in the archives, in the concluding days of August.

Up to the first of July, Mrs. Surrey's work since the beginning of September resulted in the preparation of more than 5,000 cards, the total number now being 29,421 and representing nearly that number of documents. She also made, for the benefit of Miss Donnan's volumes, a special calendar of papers relating to the slave trade into French Louisiana, and prepared, from the materials of which she has now so great a mastery, a paper on the development of agriculture in the Mississippi Valley during the French régime, which was read at the meeting of the American Historical Association at St. Louis in December, and is to be printed in the *Mississippi Valley Historical Review.*

During the first nine years of the Department's history under the present director, 1905–1914, a large part of its attention was given to the work of preparing guides to the materials for American history in foreign archives, on the same general plan as that which is being followed in Paris, though naturally an exceptional degree of elaboration was practised in the cases of England, France, and Spain, whose archives contain far more American material than those of any other foreign countries. In 1914, when war broke out and made the conditions for work in archives unfavorable in nearly all the countries of Europe, the Department had prepared, and the Institution had published, a series of volumes which at the least afforded "first aid" to searchers for materials for the history of the United States in the chief archives of England, Spain, Italy, Germany, Austria, Switzerland, Russia, Canada, Mexico, and Cuba. The circuit was not complete, but there remained, of countries having any serious amount of materials for American history, only the Netherlands, the Scandinavian countries, Scotland, Ireland, and the West Indies.

Of the archival materials in these countries last named, what little is to be found, relative to America, in the General Register House of Scotland has been examined, as was reported a year ago, and the notes are in hand. Somewhat more was found in the Public Record Office of Ireland, as was stated last year, in reporting upon the expedition from London to Dublin made by Professor Herbert C. Bell. Since that time, however, in the course of the civil war which has been raging in Ireland, the special building in which the Irish archives were preserved has been almost wholly destroyed. The destruction of the contents was not complete, but details as to its extent have not yet been received. It is at any rate not at present expedient to think of publishing the notes, on materials mostlycommercial in their character, which Professor Bell collected.

In Russia, on the other hand, while archives and archive materials of periods prior to the communist revolution were for some time ill cared for, the various political changes of recent years have given freer access to papers once secluded. Professor Frank A. Golder, when in Russia on business of the Hoover War Collection and the American Relief Administration, has found opportunity to bring his notes concerning papers relative to American history down to later dates than those represented in his *Guide to Materials on American History in Russian Archives*, prepared under permissions accorded by the government of the Tsar and published in 1917. The additional notes now in hand are being translated into English, when necessary, and will be available for publication in some later connection, perhaps in combination with a future report on Scandinavian archives. Appropriations for this latter undertaking are not at present in sight, but negotiations are in progress which may make it possible to attain an equivalent result with little cost to the Institution.

The archives of the Netherlands were inspected for the purposes of the Department in 1919 by Mr. A. J. F. van Laer, archivist of the State of New York, who in the spring of that year made an expedition to Europe with that object in view. The engrossing duties of his official position, however, combined with the state of his health since that time, have prevented him from finishing the manuscript of his report on the numerous and important materials for American history in Dutch archives.

It remains to speak of the archives of the British West Indies. Search of the island archives themselves has not yet become practicable, for want of appropriations, except that excellent reports on those of Bermuda, the Bahamas, and Jamaica have been prepared at various periods in former years and are already in the possession of the Department. But, as was explained in last year's report, the many volumes in the West Indian section of the Colonial Office Papers, preserved in the Public Record Office in London, are the indispensable complement to the various series which are preserved in the island archives. The one can not be suitably studied without the other, either with respect to a proper understanding of the history of the British colonial empire, inclusive of the Thirteen Colonies of the mainland, or with respect to the important history of commerce between the West Indies on the one hand and the mainland colonies or United States on the other. That portion of the whole undertaking which consisted in the examination of the West Indian "classes" of the Colonial Office Papers was attacked in advance of any attempt to visit the archives of the island colonies, with the exception of the three named above.

It was reported a year ago that Mr. Bell had completed all parts of his examination of these West Indian papers in London, down to the year 1775. He has since presented, in excellent form, the inventory of American papers thus obtained. The continuance of this survey from 1775 to 1815 was intrusted to the competent hands of Miss Lillian M. Penson, of London, an accomplished student of West Indian history, who has also had the advantage of sufficient supervision on the part of Mr. Bell, during recent months spent in London, to insure a proper similarity of form between the two portions of the work. There is, however, a marked difference between the two periods, leading to a difference in the amount of matter involved. The interest of the West Indian papers of the period from 1775 to 1815 is for our purposes mainly confined to the contacts—military, naval, and commercial—between the United States, or American citizens, and the colonies of Great Britain, with which the United States was involved in two wars during the period named, one occupying the first eight of these years, the other the last three, while the years between, 1783–1812, were filled with commercial conflict and friction, owing to the policy maintained by Great Britain in respect to commerce with her colonies. Working, accordingly, on a somewhat lesser scale than that which was appropriate to the period before 1775, Miss Penson has at the date of this report nearly completed her inventory of the papers relating to the United States or its citizens in that portion of the West Indian papers which falls within the final period of forty years assigned to her care.

The question may readily arise, why, when so much attention has been given to the materials in foreign archives, so little has been bestowed on the more abundant materials in American archives, since the publication in 1907 of the second edition of Messrs. Van Tyne and Leland's *Guide to the Archives of the Government of the United States in Washington* and in 1911 of Mr. Parker's *Calendar of Papers in Washington Archives relating to the Territories of the United States (to 1873)*. The answer is not recondite. Inventories of the archives of the States have been published by the States themselves, or, in a long series extending from 1900 to the present time, in the annual reports of the Public Archives Commission established in the former year by the American Historical Association. As to the archives of the Federal Government in Washington, those portions of Messrs. Van Tyne and Leland's Guides which are now out-of-date are so because of shiftings of material effected with bewildering frequency, and still in progress, and because of enormous additional papers resulting from the war and whose future treatment and place of deposit are still uncertain. When the archive situation in Washington is stabilized by the erection of the National archive building so long and so urgently demanded, the Government or the Carnegie Institution can produce a guide which will be valid long enough to justify the labor. Toward that consummation the Director has for thirteen years, as a matter of obvious duty, and as chairman of a committee of the American Historical Association, contributed whatever effort he could.

In the work upon the *Atlas of the Historical Geography of the United States*, Dr. Paullin has during the year completed, or in some cases nearly completed, four portions of his work. First, he has completed two maps of England (and Wales), showing the sources of migration of population to New England and to Virginia, respectively, in the seventeenth century. Secondly, he has prepared and carried to its completion the map of American explorations in the West beyond the Mississippi, from 1803 to 1852, a map exhibiting the lines of some twenty-seven different explorations; and he has nearly completed the map showing French explorations in the West from 1673 to 1794. In preparing the latter, he has had the valuable assistance of Miss Louise Phelps Kellogg, of the Wisconsin State Historical Society, whose knowledge of the history of these French explorations is unrivaled. Thirdly, he has completed a series of five maps which exhibit the areas of negro, foreign, German, Irish, and Swedish and Norwegian population in the United States, as shown by the census of 1920. These maps, prepared from manuscript materials in the office of the Bureau of the Census, as well as from its printed publications, constitute the completing members of series prepared in former years, with respect to the dates of the earlier censuses. Fourthly, Dr. Paullin has devoted the latter portion of the year's work to a series of maps intended to exhibit the distribution of wealth in the United States, at various periods, and the movements of commerce. He has completed five maps showing the distribution, at various periods from 1800 to 1910, of American banks, some 30,000 in number, and he has prepared four preliminary maps showing the distribution of wealth by other methods, such as the plotting of the incidence of income taxes. He has also made considerable progress in the collection of materials for maps showing imports and exports. For all maps that have been completed, the letterpress has also been prepared. In the execution of the maps, Dr. Paullin has had, as usual, the aid of Mr. J. B. Bronson as draftsman.

Outside the archives and libraries of the national capitals, to which, in general, the systematic searches instituted by the Department have been confined, there are in the other libraries of Europe, scattered in small quantities here and there, a large number of manuscripts relating to American history. There could be no hope of making a complete methodical search for these, and descriptions of them, without the expenditure of great sums of money. It is, however, possible with moderate effort to produce a manual listing a great many of them, by the process of drawing off from the printed catalogues of manuscripts put forth by a considerable number of these libraries, or otherwise published, those items and descriptions which relate to American history. The collecting of these, and the compilation of them into a volume, has been the work intrusted to Mr. Matteson, of Cambridge, who has given portions of his time to it during the past few years. In the year now reported upon, he has nearly completed the work of collection from the catalogue materials available in the various American libraries, and it is believed that the work of compilation and of final preparation for printing can be finished by the end of the year 1922.

TEXTUAL PUBLICATIONS OF DOCUMENTS.

Miss Davenport, working in London, has made ready for publication nine more treaties, 1676–1686, for the second volume of her *European Treaties bearing on the History of the United States*, with the exception that in the case of one or two documents photographs of texts better than those of the manuscripts in the Public Record Office in London are expected to be received from Continental archives. At the date of this report Miss Davenport is leaving London, to resume work in Washington at the end of September. In London she has served as a member of the Anglo-American Committee formed as a result of the historical conference of July 1921.

Dr. Burnett's work, aside from some time spent in services to the *American Historical Review*, has consisted partly in seeing through the press the text of the second volume of his *Letters of Members of the Continental Congress*, partly in preparing the "front matter" to that volume, partly in annotation of the third volume. The second volume contains letters of the dates from July 5, 1776, to the end of the year 1777. Its text amounts to 604 pages, and embraces 795 letters, or parts of letters or diaries, containing information respecting the doings of Congress additional to that which is to be found in their printed Journals. The amount of entirely new matter, never before printed, is considerably greater than in volume I, for it is the first period of the Continental Congress, extending from its first assembling to the Fourth of July, 1776, which has most attracted the attention of historians, and for which the greatest number of letters and other documents have been put into print. The front matter to volume II, alluded to above, consists of the introduction, which Dr. Burnett has now begun to prepare, and an exhibit, now nearly completed, of the elections to membership in the Congress by the various States and of the dates of attendance of the individual members. Meanwhile, the index to the volume, of which the whole text is in page-proof, has been prepared by Mr. Matteson.

In the series which is being prepared by Dr. Stock, *Proceedings and Debates of the British Parliaments respecting North America*, the work at present going on is that of annotating the texts, gathered long since. During the year Dr. Stock has carried this work of annotation, in respect to the parliaments of England, from 1667 to 1689, the date with which the first volume is to end. The small amount of material found in the records of the Scottish parliaments, from the first references to America down to 1689, will need little time for annotation. Annotation of proceedings and debates of the parliaments of Ireland has been carried to 1650. This first volume is therefore nearly ready for the press.

It is understood that Miss Donnan, not now a member of the staff of the Department but an assistant professor in Wellesley College, can devote little more time than that of the summer vacations to the completion of the volumes on which she was engaged when she resigned from the Institution, volumes of documents illustrative of the history of the African slave trade, the sources and methods of supply, and the transportation to the American colonies, and, later, to the United States. Her work in the preceding summer having consisted in searches for appropriate documents in London, among the papers of the Royal African Company and elsewhere in the Public Record Office and in the British Museum, the results have been arriving in the form of transcripts during the year. The summer just ending has been spent in continuous labor upon the materials thus added and upon those previously acquired. In the case of such a book, embracing documents of the most various character—narratives, travelers' descriptions, minutes of the African Company's actions, logs of slavers, manifests, accounts, agreements, captains' letters, correspondence of merchants and factors, advertisements, papers in legal suits—it is not easy to define the exact stage of progress reached at any given date, but it may be said that most of the work of arrangement is done, and most of the annotation of documents dating before 1700. It should be mentioned that, in addition to sources of material already mentioned in previous reports, several transcripts of valued documents have been received from the library of the Duke of Portland at Welbeck Abbey, by the kindness of the librarian, R. W. Goulden, esq.

The work of Mrs. Catterall, in drawing off materials respecting the history of slavery from the judicial reports of the American States, has during the year been carried through the reports covering Virginia, West Virginia, the District of Columbia, Vermont, Canada, Jamaica, and England. Matter amounting to somewhat more than a volume has been accumulated, but there is a small part lacking of what should go into volume I before completion of that volume can be reported.

All the work of copying for the volumes of *Correspondence of Andrew Jackson*, and of collating the transcripts with their originals, has been completed. The last year's work has embraced the material at the War Department and that possessed by the Tennessee Historical Society, in addition to continuance and completion of the main work at the Library of Congress, in the Jackson, Van Buren, Polk, and Donelson papers. Meantime Professor Bassett, the editor of the series, has spent many weeks in the work of annotation, which has been carried well into the period of the War of 1812.

When the series of volumes of the *Correspondence of the British Ministers to the United States* was originally planned, it seemed necessary to resolve that the work of editing should be performed by the Director himself. Agreeable as the work is, and deeply as the editor is impressed with its interest and importance, it must be confessed that his normal duties have left him, since his return from Europe in November 1921, little time for its prosecution. He has made such progress as he could. Meantime, by the careful work of Miss Fisher and Miss Lockhart in London, a large mass of transcripts has been made in the Public Record Office and sent in regular fortnightly consignments to Washington. What has been thus far received, from among the Foreign Office Papers in that repository, embraces, on the one hand, the instructions and other communications sent by the successive Foreign Secretaries in London to their diplomatic representatives in Philadelphia and Washington from 1791 to 1807; on the other hand, of the more numerous despatches sent by the latter to the Foreign Secretaries, it embraces those sent from Philadelphia by the first minister, George Hammond, in the period from November 1791 to July 1795, and those sent during the ensuing period of nearly a year by Phineas Bond while he was chargé d'affaires in the interval between the departure of Hammond and the arrival of Robert Liston, the second minister. More than enough material to constitute the first volume has thus arrived.

These two series of communications—of Foreign Secretary to minister and minister to Foreign Secretary—will furnish the main substance of the successive volumes. The purpose, however, for which the series is planned, that of exhibiting the spirit and development of British policy toward America by showing, so to speak, what British officials said to each other while their diplomatic action was going on, is further subserved by making use of the correspondence of the British ministers with other British officials besides the Secretaries of State. With this in view, the editor, while in the Public Record Office in the preceding year, sought for such additional despatches in other sections than the Foreign Office Papers, and it has been deemed expedient that the transcribing carried out during the present year should include these miscellaneous gleanings, throughout the whole period to the War of 1812, in advance of the completion of the two main series of official despatches. Accordingly, the receipts of the year have embraced a considerable amount of correspondence, from the Admiralty Papers, that passed between the British ministers and British admirals on the Halifax or Bermuda station, a little from the papers of the Marquess Wellesley, at the British Museum, and much from the private papers of Francis James Jackson, envoy in 1809–10, which were years ago turned over to the Public Record Office by his representatives.

Last year's report explained the peculiar value of the private letters, outside the regular series of public official despatches, which ministers wrote to the Foreign Secretary or his assistants, or to relatives and friends in England, and described the efforts made to find such letters and obtain permission to use them. That report was dated September 1, 1921, and so did not include the results of the last five weeks of the writer's stay in London. During that time, in addition to the continuance of work in the Public Record Office and the British Museum, he visited the heirs of George Hammond and Lord Hammond his son, of Sir Robert Liston, of the first Sir Edward Thornton—chargé d'affaires 1800–1803, and father of a later minister in Washington—and of Secretary Canning, and received obliging favors from all. Since then he has received, from the Honorable Miss Hammond and her kinsman Sir George Barnes, a small but very interesting group of documents and private letters from and to George Hammond, especial interest attaching to a letter of Lord Wycombe, Shelburne's son, relating to the visit of Talleyrand to the United States. The Misses Thornton also searched their family correspondence, and allowed portions to be copied from an autobiographical memoir of Sir Edward Thornton's early life and diplomatic experiences, prepared by him in later years. Mr. G. H. Liston-Foulis, of Edinburgh, unable at the time of the editor's visit to that city to examine the papers of Sir Robert Liston, has been so good as to carry out the examination of a large part of them since that time.

Mention was made in the last report of the large collection of papers of Sir Charles Bagot, minister in Washington from 1816 to 1819, preserved at the celebrated residence of Levens Hall in Westmoreland, and of the cordial invitation to come and examine them which had been received from their owner, Mr. Richard Bagot, a noted writer. But before the editor could avail himself of this kind invitation, Mr. Bagot was attacked by an illness which proved fatal in October, about the time when the Director was leaving Europe.

It is impossible to conclude the record of that expedition without making grateful and affectionate acknowledgment of the kindness with which the late Lord Bryce constantly furthered its purposes and those of the contemplated publication, from the moment when its design was first described to him. It was by his means that, at the beginning, the necessary permissions were obtained from the then Secretary of State for Foreign Affairs, Mr. Balfour. Unwearied in aiding the preliminaries of the expedition, Lord Bryce showed himself particularly so in the four days that intervened between the Director's arrival in London on July 4, 1921, and the veteran statesman's departure for his last voyage to America, to lecture in the Institute of Politics at Williamstown. In those crowded days before sailing, when this marvelous man of eighty-four was making a public speech somewhere every day, he nevertheless found time, of his own motion, to confer helpfully upon this undertaking of a single American historical scholar, and to write, even to the parting with the pilot-boat, letters of introduction that would promote its success. From his final service to mutual understanding between Great Britain and America he did not return to London till after the writer of this report had left England, but, bearing the expedition in mind along with the interests of countless other friends, he soon afterward, on one of the last days of his life, wrote by way of interested inquiry as to its success. If the undertaking succeeds, it will owe a great debt to him, not only for all this constant helpfulness toward its execution, but for the demonstration that his ambassadorship and his whole life afforded, that Anglo-American relations can be discussed serenely and without passion, sympathetically and with increased understanding of past and present conditions, and best discussed by those who would wish to see them improved.

Throughout the history of Anglo-American diplomacy, and somewhat especially in the time of the French war, 1793–1815, the relations of the British ministers in Philadelphia and Washington with the British officials in Canada were close and important. The Public Archives of Canada, visited in November 1920, yielded notes of many letters. Photostat copies of these have been obtained by the kindness of Mr. David W. Parker, chief of the manuscript room at Ottawa, formerly a member of the staff of this Department, and notes of others have been supplied out of his unrivaled knowledge of the contents of his archives. By the good offices of Mr. Harry Piers, provincial archivist of Nova Scotia, transcripts of several interesting letters of early British ministers to governors of that province have been added to the Department's collections. Other transcripts are being made. Similar acquisitions from the archives of Newfoundland are in course of preparation.

Mr. William L. Clements, of Bay City, Michigan, has with much generosity enabled the Department to take copies of a very interesting correspondence belonging to him, amounting to eighteen letters, 1791–1793, between Hammond and Colonel John Graves Simcoe, the first governor of Upper Canada. From the papers of Vice-Admiral Sir George Berkeley, in the Toronto Public Library, Dr. George H. Locke, its chief librarian, has supplied photostat copies of a number of interesting letters of early British ministers, chiefly Anthony Merry and David M. Erskine, addressed to Berkeley while he was in command on the American coast.

The matter of the Bandelier collection of documents obtained in Spain and relating to the Pueblo Indians and the history of the Rio Grande region, though it did not originate with the Department, may now be regarded as a part of its work in the textual publication of documents, since the collections made by Dr. Bandelier and Mrs. Bandelier in Spain in 1914–1916 were in 1917 turned over to the Director for general supervision of the editing and preparation for publication. The editing was at that time confided to Dr. Charles W. Hackett, now a professor in the University of Texas. Although Dr. Hackett's work has been impeded by various changes of place and resulting obligations of new work, it is a pleasure to be able to report that the complete manuscript of the first of the four volumes, which the collection will make when printed, is now in the possession of the Department. Careful examination of the manuscript shows that the work of transcription, translation, comment, and the supplying of introductions has been performed with scrupulous painstaking and accuracy, and the manuscript for volume I is now ready to be offered for publication. It contains two parts of the material collected: first, that relating to the period in the expansion of Spain in North America comprised between 1492 and 1590, and secondly, that relating to the founding of New Mexico, 1543–1609. In the first section, after a comprehensive introduction, Dr. Hackett presents a body of reports relating to the service and merits of discoverers and conquistadores of New Spain, a body of cédulas and letters relating primarily to Indian affairs in Nueva Galicia and Nueva Vizcaya and adjacent regions in the later years of the sixteenth century and several documents relating to the early colonial administration of New Spain—all new material, and of much interest. The second section presents some fifty new and unpublished documents respecting the exploration and settlement of New Mexico and its organization in its earliest years.

MISCELLANEOUS OPERATIONS.

As heretofore, the editing of the *American Historical Review* has been carried on in the office of the Department and by its staff. The American Historical Association and various other historical organizations have received such aid as could appropriately be rendered in respect to investigations in Washington and other services, and many queries from individuals have been answered, or transcripts of documents procured for them.

The Director has served as one of the two representatives of the American Historical Association in the American Council of Learned Societies, and as a member of the committee of ways and means in that council. He has also, in the later portion of the year, served as a member, and chairman, of the American committee appointed to aid in the preparation for the Fifth International Congress of Historical Studies, to be held in Brussels in April 1923. Mr. Leland has continued to direct the work of transcribing documents in Paris archives for the Library of Congress. He has also, in conjunction with Dr. N. D. Mereness, partly completed a monograph on the war archives of the United States for Professor Shotwell's series of volumes on the Economic and Social History of the World War—a series conducted under the auspices of the Carnegie Endowment for International Peace. Dr. Stock has given courses of historical instruction in the Catholic University of America.

DEPARTMENT OF MARINE BIOLOGY.[1]

ALFRED G. MAYOR, DIRECTOR.

The unfortunate death of Dr. Mayor occurred before he had accumulated material for his annual report. The investigators, however, who have been engaged in researches during the past year in collaboration with the Department of Marine Biology had been asked by him to prepare reports for this purpose; these reports are printed herewith.

The work of reconstruction of the Tortugas Laboratory, which was begun in 1921, as reported by the Director last year, was completed during the past season under the direction of the chief engineer, Mr. John W. Mills. The interior of the new laboratory building was finished and an iron-piered wharf extension was built. The moat surrounding Fort Jefferson having been wholly abandoned by the U. S. Navy, the breach in the moat wall, caused by the hurricane of 1919, was repaired last year and *Cassiopea* has reappeared. Dr. Mayor, therefore, had the satisfaction of realizing that the Tortugas Laboratory was in an excellent state of repair and that its facilities for effective work had never been better.

Attention may be directed to the observation in the report of Dr. Bartsch with regard to the rapid reestablishment of adequate vegetation and animal life in the waters of Florida Bay.

During the year the *Anton Dohrn* was equipped especially for work in the Gulf Stream, with cables, current meters, and sounding machines, in expectation that extensive investigations in this region would be undertaken subsequently.

Owing primarily to the Director's continued ill health, only a short season was planned at Tortugas, but a number of investigators whose researches required extension or completion accepted invitations to visit Tortugas or to continue work elsewhere.

The following studied under the auspices of the Department during the year:

Dr. Paul Bartsch, Florida Keys (Miami to Tortugas), May 7 to May 23. Breeding experiments with cerions.
Professor Ulric Dahlgren. Study of luminous Crustaceæ and fishes in vicinity of Miami, Florida.
Professor John H. Gerould. Studies on the Pieridæ.
Professor E. Newton Harvey. Production of light by animals.
Professor C. B. Lipman, assisted by Mr. R. L. Starkey, Tortugas, June 6 to June 23. The precipitation of calcium carbonate by marine bacteria.
Professor William H. Longley, Tortugas, June 6 to July 24. The habits of Tortugas fishes.
Dr. Alfred G. Mayor, Tortugas, May 5 to June 24.
Dr. Sergius Morgulis, Tortugas, June 6 to July 24. Studies of the blood of the Tortugas crawfish, *Panulirus argus*, and of a nurse shark.
Captain Frank A. Potts, Tortugas, June 27 to July 24.
Professor Asa A. Schaeffer, Tortugas, June 6 to July 3. Marine amebæ.
Professor William A. Setchell. Reconnaisance of the vegetation of Tahiti, with special reference to that of the reefs. May 16 to July 19.
Dr. T. Wayland Vaughan. Studies of fossils from Walu Bay and of corals and bottom samples from Samoa and from the Bahamas and Florida.

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[1] Situated at Tortugas, Florida.

REPORTS OF INVESTIGATORS.

Breeding Experiments with Cerions, by Paul Bartsch.

Dr. Bartsch continued his cerion studies at the Laboratory from May 7 to May 23.

A careful examination of the hybrid cerion colony on Newfound Harbor Key was made and many dead specimens were gathered and carried to Washington for detailed study. This colony continues to be of great interest on account of the extreme diversity of form, sculpture, and markings produced by the crossing of *Cerion viaregis* with *Cerion incanum.*

Thanks to the good offices of the Navy Department, a naval seaplane, under the command of Lieutenant Noel Davis and Lieutenant L. F. Noble, was detailed to Dr. Bartsch for use in examining the Florida Keys. By the use of this machine it was possible to examine all the keys lying between Miami and the Tortugas, including those in the Bay of Florida, west to Cape Sable, and to mark on charts all grass plots on the keys within this region. It is in such grassy meadows that the native cerions make their home. Dr. Bartsch has for a number of years studied the extent of distribution of the native species. This, by means of the boat facilities, has proved a rather trying task, because it was found necessary to break through mosquito infested mangrove fringes to reach the interior of the keys, where the grassy plots usually occur, and in the larger keys many such excursions were made necessary in order not to overlook any possible colony. By means of the reconnaissance work done this year, it will be easy to go directly to the places where meadows are now known to exist and make the necessary examination for the mollusks in question. It is believed that about a year's work was saved by the use of the seaplane.

Incidentally it was found that the milky, oozy condition characteristic of the waters of Florida Bay for some years has disappeared, and that adequate vegetation and animal life are rapidly reestablishing themselves in the region. This is interesting, because the same state of changed affairs was noted on the west coast of Andros, in the Bahamas, last year. It seems to indicate that the partial depletion of the Florida continental-shelf fauna and flora was not due to local conditions, but to widespread oceanographic factors. A comparison of the fauna and flora now establishing itself, with that of the past, promises an unusually fine field for a study in distribution.

At the Tortugas, all the cerion colonies were examined and measurements and photographs were taken of 43 of the first generation of Florida-grown *Cerion uva,* the parents of which came from Curaçao.

It was found that the individual pairs of specimens planted in the cages last year and also the larger aggregations planted in cages had all died. Experimenting during his stay at the Tortugas led Dr. Bartsch to believe that this was due to the fact that the cages had been covered with fine-meshed wire, this screening preventing the dew from reaching the interior of the cages, and it is believed that the deaths were due, therefore, to a want of moisture, for as a rule there is a heavy dew on Loggerhead Key at night, the time at which cerions are active.

For that reason new plantings were made and a narrow fringe of wire only was placed around the edge of the top of the cages to prevent the organisms from creeping out, permitting the formation of dew within. A young specimen of *Cerion viaregis* and of *Cerion incanum*, the former gathered from the planting at the south end of Loggerhead Key and the latter at Key West, were placed in each of cages 1 to 44. In cage 45 a colony of 77 young *Cerion incanum* was placed, while cages 47 to 56 contain the following combinations:

No. 47 contains 25 C. incanum and 25 C. viaregis.
No. 48 contains 25 C. incanum and 25 C. casablancase.
No. 49 contains 25 C. incanum and 25 C. uva.
No. 50 contains 25 C. incanum and 25 C. crassilabre.
No. 51 contains 25 C. viaregis and 25 C. uva.
No. 52 contains 25 C. viaregis and 25 C. crassilabre.
No. 53 contains 25 C. casablancæ and 25 C. uva.
No. 54 contains 25 C. casablancæ and 25 C. crassilabre.
No. 55 contains 25 C. uva and 25 C. crassilabre.
No. 56 contains 25 C. viaregis and 25 C. casablancæ.

A new cage was made, the walls of half of which were covered with wire and the other half with cheese cloth. In each of these a colony of cerions was placed, and in both the top was left open, excepting a fringe of wire to prevent the escape of the specimens. Thus it is hoped to determine whether by any chance the attachment of the mollusks to the wire meshes of the side of the cage may have a killing influence, possibly through the heating of the wires.

On May 23 a colony of 500 each of marked specimens of *Cerion viaregis* and *C. incanum* was planted in a small, low meadow at the east end of Man Key and another of equal numbers in a similar location on the north end of the little key to the east of Man Key, which may be called Boy Key. Both these colonies are marked with stakes. These two plantings were made with the hope of duplicating the hybrid conditions on Newfound Harbor Key, thus materially reducing the danger of losing these experiments through fire, which is always a menace to our work on these keys.

Birds of the Florida Keys.

During Dr. Bartsch's stay at the Tortugas, the Navy Department, under the direction of the Biological Survey at Washington, moved the warden's house on Bird Key. This change necessitated the moving of 2,420 tern eggs which were on the point of hatching. These eggs were placed in nests adjacent to the region laid bare by the moving, and in no instance did the birds, upon whom an extra egg had been bestowed, refuse to assume the duty assigned. Very little damage was therefore done in the moving, but probably an increase of young occasioned, because the robbed parents soon replaced the lost egg and reoccupied the territory temporarily laid bare by the activities of the artisans.

Dr. Bartsch reports the need for shade trees or shrubbery to protect the young birds from the glaring rays of the sun, the vegetation having mostly been carried off by recent hurricanes.

Study of Luminous Crustaceæ and Fishes in Vicinity of Miami, Florida, by Ulric Dahlgren.

In the latter part of January, Dr. Dahlgren went to Miami, Florida, to study the luminous crustaceæ and fishes. The principal object was to find a species of *Cypridina* that gave a greenish or yellowish light that might be used in Dr. Harvey's chemical work for experiment with the blue-light form

Cypridina hilgendorfii. Lund had described such a green-light form from Jamaica, and it was desired to find a supply nearer home. Such an animal was found through the kind help of Dr. Louis Mowbray, director of the Miami Aquarium, and seems to be a more or less pelagic species which comes on the coast in large quantities at intervals. Arrangements are being made to secure the material to be used as stated. Many interesting notes were made on other luminous forms, but the fishes were not found with the apparatus at our command.

Studies on the Pieridæ, by John H. Gerould.

The discovery in 1920 and 1921 of blue-green and olive-green mutations in caterpillars of *Colias philodice,* involving changes in the hemolymph, in eye-color, and other characters of the prospective butterfly, led in 1922 to a spectroscopic study of the blood of caterpillars. With the assistance of Dr. J. W. Tanch, of the Department of Physics of Dartmouth College, an expert in spectroscopy, photographs have been taken showing the absorption effects produced by the hemolymph of the leaf-eating caterpillars of various moths and butterflies, by solutions of chlorophyl and xanthophyl, and by mammalian blood. Attention is being given to differences existing between different species, between the different sexes of the same species, and particularly to the relation of chlorophyl to green and yellow blood-pigments in leaf-eating caterpillars. That these pigments are derived from the chlorophyl of the food with no considerable change was assumed in my paper on the blue-green caterpillar (Jour. Exper. Zool., vol. 34, pp. 385–412), on the basis of the early researches of Poulton and the more recent investigations of Geyer. Actual photographs of the absorption spectra upon which these conclusions were based have never been published, but improved instruments and methods now make it possible to prepare for publication excellent detailed spectrograms.

Adverse climatic conditions in the winter of 1920–21 (extraordinary dryness of the soil and, possibly, the remarkably long periods of intense cold) destroyed my selected stocks of hibernating blue-green and olive-green caterpillars before spectroscopic tests could be applied to their blood, and temporarily almost exterminated in this region the species (*Colias philodice*) to which they belong. But stock of *Colias eurytheme* var. *eriphyle,* the yellow western variety of the "orange-sulphur" butterfly, sent me by Professor P. W. Whiting from Nebraska and Wyoming, is being inbred in search of similar mutations.

Breeding experiments with a cabbage butterfly, *Pieris napi,* represented in America by the variety *oleracea,* the "gray-veined white," have been started in collaboration with Professor J. W. H. Harrison, of Armstrong College, Newcastle-upon-Tyne, England. A cross-mating between *Pieris rapæ* ♀ and *P. napi* var. *oleracea* ♂ has been obtained, but efforts to produce the reciprocal cross have not been successful.

Mr. Lloyd C. Fogg, a graduate student, has rendered excellent assistance in this work.

Report of Investigations on the Production of Light by Animals, by E. Newton Harvey.

Research was continued on the chemical processes underlying the production of light by organisms. Specimens of *Cypridina hilgendorfii,* dried under the direction of Professor Chiomatsu Ishikawa, of the Imperial University

Agricultural College at Tokyo, Japan, have been received from time to time, and it gives me great pleasure to acknowledge the kindness and interest of Professor Ishikawa in supervising the collection of this material for me. *Cypridina* is by far the most favorable organism for chemical research, and a source of supply in this country is much to be desired. If an abundant supply of these organisms were available, the chemical nature of luciferin, the substance oxidized with light production, could unquestionably be worked out and its synthesis possibly accomplished.

Such abundant stock of *Cypridina* is not at present available, and accordingly I have directed the research along three lines which do not require so large an amount of material, viz:

(1) Studies on the specificity of luciferin and luciferase, to ascertain whether the luciferin of one species of luminous animal will give light if mixed with the luciferase of another species, and vice versa.

(2) Studies on the methods of reduction of oxyluciferin to luciferin. By this means luciferin can be regenerated from its oxidation product, oxyluciferin, and continuous luminescence produced.

(3) Studies on the kinetics of the luciferin ⇄ oxyluciferin reaction. This problem has been ably investigated by Dr. William R. Amberson, and his résumé of the work follows.

The full papers embodying the above investigations will be published during the year in the following journals:

Harvey, E. N., Studies on bioluminescence: XIV. The specificity of luciferin and luciferase. Jour. Gen. Physiol., vol. 4, 285–295 (1922).

Harvey, E. N., Studies on bioluminescence: XV. Electro-reduction of oxyluciferin. Jour. Gen. Physiol. (1922).

Amberson, Wm. R., Kinetics of the bioluminescent reaction in *Cypridina*, I and II. Jour. Gen. Physiol., vol. 4, 517–558 (1922).

The complete account of the author's work on the luminous fish of the Banda Islands, *Photoblepharon* and *Anomalops*, will appear in the forthcoming volume of Contributions from the Tortugas Laboratory.

Specificity of Luciferin and Luciferase.

Cypridina luciferin has been mixed with extracts of 14 different groups of luminous animals, so prepared that they should contain the luciferase of each group. These groups were: (1) cystoflagellates (*Noctiluca*); (2) pennatulids; (3) medusæ; (4) ctenophores; (5) odontosyllid worms; (6) polynoid worms; (7) chætopterid worms; (8) polycirrid worms; (9) schizopod crustacea (*Meganyctiphanes*); (10) fire-flies; (11) mollusks (*Pholas*); (12) ascidians (*Pyrosoma*); (13) balanoglossids (*Ptychodera*); (14) fish (*Photoblepharon*). In no case did light appear. *Cypridina* luciferase has also been mixed with extracts of the above 14 groups, so prepared that they should contain the luciferin of each group. In no case did light appear. It is, therefore, concluded that luciferin and luciferase of various forms are specific to a high degree and will not react with luminescence if produced by unrelated animals. If the relationship is close, luminescence will appear. Thus, *Cypridina* luciferin will react with the luciferase of *Pyrocypris*, another genus of ostracods, and vice versa. We must, therefore, consider the luciferins or luciferases to be a group of chemical substances, differing slightly in different orders of animals as do the hemoglobins of different vertebrates.

Many hundreds of extracts of nonluminous forms have been mixed with *Cypridina* luciferin in the hope of finding some form producing an enzyme capable of oxidizing *Cypridina* luciferin with light production; also, nonluminous animal extracts have been mixed with *Cypridina* luciferase in the hope that some substance in these extracts might oxidize with light production. In either case the results have been always negative. Extracts of nonluminous forms do not react to produce light with *Cypridina* luciferin or luciferase. They are neutral so far as effect on the *Cypridina* luminescence is concerned, neither increasing or decreasing the intensity of this luminescence.

However, one luminous form, *Ptychodera*, allied to *Balanoglossus*, does inhibit the *Cypridina* luminescence. This animal, obtained in the sand under rocks near Hamilton, Bermuda, produces, when irritated, a luminous slime, whose light disappears rather quickly. If the slime, after the light has gone, is added to a luminescent mixture of *Cypridina* luciferin and luciferase, the *Cypridina* light is dimmed, or, if weak, disappears entirely. This is the only instance that I have noted of inhibition of *Cypridina* luminescence by extracts of other animals. The *Ptychodera* slime smells strongly of iodoform, but whether the odor is really due to iodoform or not is unknown. Iodoform has no effect on *Cypridina* luminescence, so that some other unknown material in the *Ptychodera* extract is responsible for the inhibition.

REDUCTION OF OXYLUCIFERIN.

When luciferin oxidizes in presence of luciferase with light production, oxyluciferin is formed. The oxyluciferin can be reduced to luciferin again by various methods, and the luciferin $\rightleftarrows$ oxyluciferin equilibrium is obviously fundamental for the student of bioluminescence. This equilibrium can be shifted toward the luciferin side in the presence of nascent or active hydrogen produced in various ways, and conversely, under proper conditions, luminescence may be used as a test for nascent or active hydrogen. Thus, if we place a strip of Mg metal in a solution of oxyluciferin and luciferase, a luminescence will appear over the surface of the Mg. The Mg dissolves in water with the liberation of nascent hydrogen, which in turn reduces the oxyluciferin near the metal to luciferin. The luciferin is then oxidized in presence of luciferase and dissolved oxygen with light production. Other metals, as Al, Mn, Zn, and Cd, also luminesce over their surface in oxyluciferin-luciferase solution, despite the fact that no hydrogen, visible as bubbles, is given off by these metals in water. A microscopic film of nascent hydrogen must be formed over their surface which is replaced as it is used up in reducing the oxyluciferin.

The above-mentioned metals all stand low in the electro-chemical series. If they are touched to any metal higher in the series, like Cu or Pt, and dipped in salt solution, a galvanic cell is formed, in which the Cu or Pt act as local cathode and reduction processes occur there. Consequently, if we touch with Pt a piece of Zn immersed in a solution of oxyluciferin and luciferase to which some NaCl is added to render it a conductor, the Zn ceases to luminesce and the Pt luminesces brightly. Nascent hydrogen is now formed at the Pt surface, reduces the oxyluciferin to luciferin, which is then reoxidized with luminescence in presence of luciferase and oxygen. A whole series of metal couples have been investigated and light appears at the cathode in accord with expectation.

The electro-reduction of oxyluciferin can be brought about at the cathode when a current from an external source is passed through a solution of oxyluciferin and luciferase, plus some NaCl to render it a conductor. With smooth Pt electrodes, a potential difference of about 1.8 volts is necessary to produce a just-visible luminescence at the cathode, and with 2 volts the light is quite bright. No light appears at the anode. Again we have reduction of oxyluciferin by the nascent H formed at cathode and immediate reoxidation of this in presence of the luciferase and dissolved oxygen.

Molecular hydrogen is unable to reduce oxyluciferin, but will do so in presence of a catalyst, such as palladium. If a sheet of Pd is palladinized, exposed to a hydrogen atmosphere, and then placed in oxyluciferin-luciferase solution, the whole surface of the Pd will glow. Palladinized Pd not exposed to hydrogen, or exposed to oxygen, will not glow. The Pd possesses catalytic action by virtue of some power of converting hydrogen into the active or atomic form. Oxyluciferin is then reduced in a thin layer over the Pd surface and is immediately reoxidized with light production by the luciferase and oxygen in the layer near to the Pd surface.

It would appear that the reduction of oxyluciferin is a hydrogenation, and, like other hydrogenations, is presumably exothermic. The equilibrium equation would be:

$$\text{oxyluciferin} + H_2 \rightleftarrows \text{luciferin} + x \text{ cal.}$$

When luciferin oxidizes and is converted to oxyluciferin with dehydrogenation, i. e., when the reaction proceeds in the opposite direction, we should require an absorption of heat. However, as the hydrogen is probably removed by combination with the oxygen to form water, we have an exothermic reaction proceeding at the same time, and the total heat production will be the resultant of these two reactions. As one is exothermic and the other endothermic, it is possible that the two will balance, and almost no temperature change will occur.

$$\text{luciferin} = \text{oxyluciferin} + H_2 - x \text{ cal.}$$
$$H_2 + O = H_2O + 58.3 \text{ cal.}$$

No temperature change has thus far been demonstrated with certainty to accompany animal luminescence.

It should be noted that, by passing hydrogen over a palladinized surface in contact with oxyluciferin, luciferase, and oxygen, we have a means of producing a continuous luminescence by hydrogenation and dehydrogenation. The final change occurring is the union of hydrogen and oxygen to form water. With a constant supply of oxygen and hydrogen, such a luminescence should continue for an indefinite period, or until the luciferase and luciferin are changed by some secondary reactions.

It should also be noted that luminous animals need not continuously produce luciferin from some simpler substance, but may utilize their store of luciferin again and again, reducing the oxyluciferin, and then reoxidizing, the dominant process dependent on the conditions within the photogenic cell. We thus have great economy in the chemical processes underlying bioluminescence, as we have great economy in the physical make-up of animal light, the production of those wave-lengths alone which affect the eye.

Kinetics of the Bioluminescent Reaction in Cypridina, by W. R. Amberson.

The rate of decay in the light produced when aqueous solutions of *Cypridina* luciferin and luciferase are mixed has been followed, and the relative light intensities along the course of the reaction have been evaluated by a method of photographic photometry. In this method a photographic record is taken of the light issuing from a narrow slit window in a blackened glass container, within which the reacting solutions are placed. A photographic film is revolved, by an accurate kymograph, at constant speed past the window. Simultaneous studies of two solutions are made by the use of two identical containers, and in this way the effect of changes in luciferase (enzyme and luciferin (substrate) concentrations, the temperature coefficient, and other problems have been studied.

The densities of the films along the course of the reaction are evaluated, after development, by the use of the optical pyrometer. In addition to the two moving records of the bioluminescence, there is impressed upon each film a series of 15 calibration exposures, in which *Cypridina* light itself is used as the light source. These 15 exposures give a graded series of densities. The relative intensities of the light producing these densities is accurately known. A curve of blackening can then be drawn for each separate experiment, and the unknown intensities along the moving records are referred to this curve for evaluation.

The results of these studies may be summarized as follows:

(1) The decay curve of the light produced in the course of the luminescent reaction in *Cypridina* is, after the first second, in complete agreement with the theoretical expectation for a mono-molecular reaction, if light intensity at any instant is assumed to be proportional to reaction velocity at that instant. For such a reaction (straight-line form):

$$\text{Log } l = -kt + \log Ak.$$

where l = light intensity, k = velocity constant, t = time, A = initial concentration of the single reactant.

The experimental values satisfy this equation.

(2) The first second or two of the reaction is characterized by a brilliant initial flash, whose value is much too high to accord with the succeeding intensities and with the above formula. This high initial reaction velocity may be an indication of a heterogeneous system.

(3) Identical solutions run simultaneously give decay curves with check within the limits of the photographic error.

(4) Stirring does not affect the reaction velocity or the form of the decay curve.

(5) Reaction velocity is proportional to enzyme concentration.

(6) Changes in the concentration of the substrate do not affect the value of k when all other factors are held constant. A diminution of luciferin concentration results only in a decrease in the value of the y intercept, log Ak. The two straight-line plottings for two different concentrations are parallel.

(7) The temperature coefficient is high, being about 4.5 for the 15° to 25° interval and 3.0 for the 25° to 35° interval.

Further Studies on the Drew Hypothesis of $CaCO_3$ Precipitation in Sea-Water, by Charles B. Lipman.

The results of my Samoan investigations of 1920, reported briefly in the Year Book of the Carnegie Institution, cast grave doubt on the validity of Drew's hypothesis, which aims to account for deposits of precipitated $CaCO_3$ in the sea by ascribing them to the specific precipitating action of a bacterial organism now named *Pseudomonas calcis.* Briefly recapitulated, my data of 1920 indicated, among other things, that there is no evidence, in the first place, that the precipitation of $CaCO_3$ occurs in ordinary sea-water, but only in artificial media containing large quantities of calcium salts of organic acids. In the second place, even under the conditions of such artificial media as those just mentioned, *P. calcis* is only one of many different organisms which possess the power of precipitating $CaCO_3$; hence that power is not to be considered specific, as, for example, is that of the nitrifying bacteria in forming nitrates, and hence the name *P. calcis* is misleading and possibly a misnomer.

With these conclusions before him, the late Dr. A. G. Mayor decided that it would be wise for me to continue my studies on this subject, and preferably at Tortugas, in which region Drew did much of his work and formulated his hypothesis. Dr. Mayor, therefore, invited me to continue my studies in 1921 by joining the Laboratory staff at Tortugas. I was unable to do so then, but found it possible to accept a renewed invitation for the summer of 1922. My experiments at Tortugas were more elaborate than those which I carried out in Samoa, and while in some respects the results were different in detail from the earlier ones, there is no difference in principle. From these results I have become more firmly convinced than ever that no evidence is at hand in support of the Drew hypothesis as an explanation of the mechanism of $CaCO_3$ precipitation in natural sea-waters; that the conclusions which I reached in 1920 are essentially sound; that in addition an understanding of the elements of ionic equilibrium in salt solutions renders clear the method by which $CaCO_3$ may be precipitated in sea-water. All these assertions are supported by experimental data in my possession.

The Fishes of Tortugas and Their Habits, by W. H. Longley.

In the seven weeks from June 6 to July 25 distinct progress was made in my research, now carried on at Tortugas for eight seasons.

In photographing fishes in their natural surroundings, thoroughly satisfactory results were obtained and many negatives secured suitable for illustrating the final report of the investigation. With increasing experience it has been found possible to reduce the time of exposure of plates materially. For general work one thirty-fifth of a second is sufficient, and under exceptional circumstances the time required to secure a picture with stop 8 may be 0.01 second or less.

In addition to one species, apparently new to science, the following (not hitherto known from this locality) were observed: *Mycteroperca tigris, M. dimidiata, Hœmulon bonariense, H. carbonarium, Alutera scripta, Chromis multilineatus, Iridio garnoti,* and *Sparisoma chrysopterum.* Of these, the last three at least appear to be new to the United States fauna.

Of other species, the following, which are not very abundant, were observed or discriminated for the first time: *Aulostomus maculatus, Decapterus punctatus,* *Hæmulon album, Anisotremus surinamensis, Chromis insolatus,* and *Lepisoma nuchipinne.*

It was observed that of the 14 species enumerated, 9 are changeable in coloration. The changes of *M. dimidiata, S. chrysopterum,* and *L. nuchipinne* are of a particularly striking character, and those of the three species of *Hæmulon* and *Aulostomus* only less so. *Decapterus* is also changeable. Upon the whole it is clear that the color changes here mentioned must be looked upon as adaptations to environments changing as the location of the fishes changes. Among species previously well known at Tortugas, adaptive color changes were observed in *Hæmulon sciurus, Scarus cæruleus, S. croicensis, S. punctulatus,* and *Pseudoscarus guacamaia.*

Observations of the most varied sort were made upon other species.

The young red parrot-fish (*Sparisoma abildgaardi*) 3 inches in length sometimes shows a pattern of longitudinal stripes, such as characterizes many labrids and scarids permanently in their adult coloration, or is displayed as one of their alternative color phases, or, it may be, appears only in their juvenile coloration. This particular phase has not been observed in mature specimens of this species.

A fish of the comparatively rare type which fishermen (probably correctly) consider to be the result of a cross between the yellow-tail (*Ocyurus chrysurus*) and the gray snapper (*Neomænis griseus*) was repeatedly seen with normal yellow-tails at their schooling-grounds. These fishes, no doubt, feed in quite other places at night, indicating that fishes possess a marked homing instinct and sense of location or direction. It has been noted in previous reports that the Hæmulidæ as a whole belong to the group of fishes that feed by night and spend the day more or less inactively about selected schooling-places. *Brachygenys chrysargyreus* and *Bathystoma rimator* apparently constitute no real exception to this rule, but in their young stages at least they feed freely by day upon plankton. A single 2-inch specimen of *Bathystoma,* one of a number feeding actively toward the tideward side of corals about which they were gathered, contained about 1,000 copepods.

Small specimens of *Mionurus puncticulatus* are sometimes found in dead tests of echinoids or in *Strombus* shells. But in a collection of 23 living *Pinna,* taken at random except for the fact that large individuals were chosen, 8 were found, most of which were larger than any others observed at Tortugas. It therefore appears that this species may almost be said to live symbiotically with the mollusk.

Ichthyologists recognize many varieties of *Hypoplectrus unicolor.* Some have considered these distinct species; others, mere color variations. To one accustomed to the rapid changes in coloration which other species undergo, these various forms appear surprisingly constant in appearance. But two at least are only alternative color phases of one species, for a single individual has been observed in nature to display alternately the coloration of *H. unicolor* and *H. unicolor nigricans.* Another individual of the variety last named also showed in the aquarium marked ability to change its shade, without, however, modifying its pattern.

The body of *Petrometopon cruentatus* is marked with numerous dark-brown spots. On the head these are smaller dorsally and larger on the side and below the eye. The conjunctiva is also spotted in such a way that no matter in what direction the eye may be rolled, with exposure of surface normally hidden, the movement is not betrayed by display of surface differing in color or pattern from that of contiguous areas. The spots on the dorsal surface of the eye agree in size with those nearest them, while ventrally it is marked with larger blotches comparable with those upon the cheek. This is a striking example of consistency in detail, which is common in the field of animal coloration.

Thalassoma nitidus and *T. nitidissima* are now recognized as alternative phases of one species, but this summer, for the first time, it became clear that the predominantly yellow *nitidissima* phase is shown chiefly by fishes near the bottom, and the slaty-blue striped or banded phase by such as swim well above it. Repeatedly schools of 2 dozen or more fishes in the *nitidus* coloration passed over almost instantaneously to the *nitidissima* type when they dashed down to the bottom to feed upon a broken sea-urchin, and underwent the reverse change at once when they returned to their original position.

Fragmentary as they are in themselves, such observations as these supplement others already on record, and it is hoped that they may at last serve to give such an intimate view of the lives of fishes as might not be secured elsewhere than in the tropics and under such favorable working conditions as prevail at Tortugas.

Study of the Blood of the Tortugas Crawfish, Panulirus argus, and an Analysis of the Blood of a Nurse Shark, by Sergius Morgulis.

In an earlier investigation (J. Biol. Chem. 50, 2, 1922) the writer examined the non-protein constituents of the blood of several marine arthropods. The data suggested a possible connection between the composition of the blood and the nutritive condition of the animal, and further study of the question along this line seemed necessary. The analyses have also shown that creatinine was completely absent in the arthropod bloods. This observation, however, was directly contradictory of certain published data, and it was therefore one of the principal objects of the investigation at Tortugas to settle this matter by an intensive study.

The blood of normal crawfish, examined practically as soon as caught, had the composition shown in the table on the following page and expressed as usual in milligrams per 100 c. c. blood.

After the crawfish remain in the live-car for one day practically all the non-protein constituents of the blood become greatly reduced in amount.

The relation of the changing composition of the blood and the nutritive condition of the animals has been studied more directly by examining the blood from the same crawfish several times in succession. This may be done with the crawfish because of the relatively large amount of blood which these crawfish contain and the apparent ease with which they recuperate after a bleeding operation. Judging by the amount of blood obtained at successive bleedings, these animals must restore their blood volume with comparative rapidity. The results found for the same animal during 44 hours are given on the following page.

	Sugar.	Non-protein nitrogen.	Urea nitrogen.	Uric acid.
Examined practically as soon as caught:				
Maximum	71	29	11	2.0
Minimum	19	15	6	0.3
After remaining in live-car for one day:				
Maximum	32	15	10	0.3
Minimum	8	7	5	..
Results for same animal during 44 hours:				
Sample of blood taken immediately	71	16	6	0.7
24 hours after first bleeding	18	14	6	0.3(?)
44 hours after first bleeding	13	10	..	+

As regards the creatinine, numerous analyses made on crawfish blood at Tortugas firmly established the fact, already discovered in my earlier studies of the invertebrate blood, that there is none present. Owing to the great concentration of the filtrates, the equivalent of 8 c. c. blood was used for a creatinine determination. The color developed with the picric-acid reagent within 15 minutes can be matched almost perfectly against a blank, with distilled water in place of the blood filtrate. If one allows a much longer time to elapse, a certain amount of red color develops, which depends primarily upon the sugar concentration of the particular sample, also on the time. Of course, even pure sugar solutions will give this reaction, if enough time is allowed, and it is possible that the quantitative results reported in the literature showing comparatively high creatinine values can be attributed to some technical error. From the writer's own experience, both earlier, extending to 25 specimens of various arthropods, and the even more extensive recent experience with the Tortugas crawfish, it can be stated unequivocally that, at any rate in these marine animals, there is no creatinine in the blood.

The question of the relation existing between the nutritive state of the animal and the composition of its blood was attacked also by direct experiment. For this purpose the blood composition was compared before and at various periods after the intramuscular injection of the following substances: urea, ammonium sulphate, glucose, sucrose. In view of the shortness of the available time, it seemed best to inject these substances in pairs, thus: urea and glucose, ammonium sulphate and sucrose. The substance was dissolved in sea-water and injected into the muscles of the thorax. The amount of urea given varied from 0.4 to 1.0 gram, of ammonium sulphate 0.5 gram, of glucose 0.4 to 0.8 gram, and of sucrose 0.4 to 0.5 gram. Briefly summarized, the results were as follows: Ammonium sulphate is rapidly eliminated from the body. Two hours after an injection it is not only completely gone, but the non-protein content of the blood is also markedly diminished. Injections of urea raise the non-protein N content of the blood in a very striking manner, and it requires perhaps no less than 12 hours for the original nitrogen-level to become reestablished.

Although in some experiments it was found that nearly all, or at any rate a very large proportion, of the non-protein nitrogen in the blood 1 to 4 hours after the injection is urea-nitrogen, as one might expect, this is not invariably the case. The writer feels, however, that this point should be reinvestigated and, if these results are confirmed, the cause for this difference should be looked after. Perhaps the most remarkable effect of the urea injection is the great increase in the uric-acid content of the blood which results from it. This is especially well shown in experiments where the crawfish had been kept in the live-car for a day or two before the experiment. The uric acid disappears from the blood either completely or practically so. The sample of blood, however, which has been taken 1 to 6 hours after the injection of urea gives a fairly intense uric-acid reaction. This gradually diminishes as the total non-protein nitrogen tends to return to the original level. Although this result may be of considerable theoretical importance, it is nevertheless essential to point out that the uric-acid determinations were made by Benedict's new method. This naturally has not been sufficiently tried out yet, though the writer knows of no substance that might have interfered with the reaction or caused the uric-acid reaction to appear.

Glucose injected intramuscularly appears very quickly in the blood, and it reaches a much greater concentration than any of the other substances studied. The blood-sugar level, of course, depends more or less directly upon the amount injected, though this is subject to considerable variation. The original blood-sugar level is reestablished in about 12 to 16 hours. The comparative slowness with which the non-protein nitrogen and the sugar-content of the blood are reduced to original concentration after an injection of urea and glucose as compared to the rapid elimination of ammonium sulphate leads to the belief that these substances are not simply thrown out, but are utilized in the metabolism of the crawfish. The behavior of sucrose as contrasted with that of glucose presents some interesting points. When a solution of sucrose is injected intramuscularly a rapid rise in the glucose-content of the blood is observed, which, however, is very much less than in the case of glucose injections. On hydrolysis the sugar concentration is found to be considerably greater, thus proving that both sucrose and glucose are present in the blood. The extra glucose must, of course, be derived from the sucrose. This brings up the very important question as to whether the crawfish possesses a sucrase or that such develops when sucrose enters the blood-stream. This problem will form the basis of a future research. It is enough to mention here that already within the first hour after the injection a considerable amount of the sucrose is split up into monosaccharide groups. The writer is unaware that sucrose ever occurs in the normal diet of the crawfish. In one crawfish the curve of distribution of sucrose and glucose (and probably levulose) in the blood was traced for 93 hours. At that advanced time 8 mg. of hydrolyzable sugar were still present, though the blood-sugar level had almost returned to the normal.

AN ANALYSIS OF THE BLOOD OF A NURSE SHARK.

The shark was captured and brought immediately to the laboratory, where a sample of blood was obtained directly from the animal's heart. The sample was taken in less than an hour from the time of its capture. The blood was analyzed according to the Folin-Wu system, except that the new Benedict method was used for the uric-acid determination. The deproteinized blood filtrate had the following composition per 100 c. c. blood:

	mg.
Non-protein nitrogen	1,299
Urea nitrogen	1,182
Creatinine	13.3
Uric acid	0.9
Sugar	77

Investigations by Frank A. Potts.

A CASE OF ASEXUAL REPRODUCTION.

Among the chætopod fauna of the Tortugas in July a very small but abundant worm was studied, belonging to the genus *Ctenodrilus*, which has furnished classic material for the study of asexual reproduction in the past, but is so sporadic in its distribution that it has not received adequate attention. The species found in the Tortugas is a typical member of the "turtle-grass" fauna, and is green in color. There are several (3, 4, or 5) median segments, each one of which is capable of producing a new worm, and they grow in size and differentiate until the parent appears as a chain of loosely connected daughter zooids. Until separation actually occurs the segments do not show any external signs of the secondary segmentation, with the exception of the differentiation of a head, but anterior and posterior zones of proliferation are established and the full number of segments is formed very soon after separation of the zooid. Sexual reproduction has never been observed in the genus, but it is interesting that the worm disappeared from its habitat toward the latter part of the month.

SWARMING OF THE ATLANTIC PALOLO.

The Atlantic palolo (*Leodice fucata*) swarmed this year on July 16, the day before the last quarter of the moon. Very large numbers of Heteronereids swarmed at the same time, an association which does not seem to have been recorded in previous years. Small Heteronereids of less than 1 cm. in length were collected, but it has not been determined whether these belong to the same species as the larger forms.

EXPERIMENTS ON THE FEEDING OF TEREDO.

A floating plank was taken in tow and found to be infected by *Teredo*. A section weighing about 800 grams (containing about 70 shipworms) was cut off and kept in an aquarium supplied with filtered sea-water only. Every day at the same time the section of wood was changed to a new aquarium, the feces discharged during the past 24 hours collected, and their dry weight estimated. The experiment was continued for 10 days, and the yield of wood from the burrows kept at a high level throughout. Eggs were laid by many individuals, and at the end of the experiment, when many shipworms were preserved, they were nearly all found to be sexually mature, while at the beginning comparatively few of those examined were at that stage.

While these experiments extended over only a short period, they tend to prove that the shipworm can live, perform its work normally, and reproduce without the possibility of using plankton as food. The ingestion of wood fragments by the liver cells has already been observed by the author and points unmistakably to the direct utilization of wood in the nutrition of this animal.

On the Distribution of Marine Amebas, by A. A. Schaeffer.

For some reason the summer of 1922 was not as favorable for the growth of marine amebas in the vicinity of Tortugas and Key West as several previous seasons were. Careful and continuous search brought to light only 5 new species of amebas, and of the 22 species previously reported from Tortugas only 8 were seen this summer. The unfavorable conditions, whatever they were, therefore affected the distribution of species already described as well as those still unknown to science. Of the 5 new species, 2 belong to the genus *Thecamœba* Fromentel and one each to the genera *Hyalodiscus* Hertwig and Lesser, *Cochliopodium* H. and L., and *Pontifex* Schaeffer. The 8 previously reported species, which were again seen this season, are: *Cochliopodium gulosum, Dactylosphœrium acuum, Flabellula citata, F. mira, Mayorella conipes, M. crystallus, Thecamœba orbis, T. rugosa,* and *Trichamœba sphœrarum.* These 8 species and a number of others are described fully in a large illustrated monograph now in the hands of the publisher. In addition to these species of amebas, it may be added that 2 species of fresh-water amebas, *Thecamœba verrucosa* Ehr. and *Amphizonella violacea* Greeff, were found in abundance in an old abandoned cistern in Key West; and two species of *Endamœba* Leidy were found in the alimentary tract of the small burrowing cockroach on the Tortugas Keys, but my time was not sufficient to study these carefully. About 100 cockroaches were examined for parasitic amebas and at least 30 of these bore recognizable amebas in the semi-fluid feces, which could readily be squeezed from the rectum without apparent injury to the cockroach. Large numbers of ciliates of several species were also present as parasites in a large percentage of the cockroaches. The larger species of *Endamœba* was about 15 microns in diameter when spherical, and the smaller species about 8 microns.

At least 3 other undescribed species of marine amebas were observed, but the number of individuals was too small for a satisfactory description.

As soon as new species of amebas are discovered the question of their distribution arises. For those that live on bacteria one can adopt common bacteriological methods to determine their occurrence. One such preliminary experiment, which had for its object the determination of the distribution of amebas belonging to the genus *Flabellula* in open sea-water off Loggerhead Key, to the north, was made as follows:

104 bottles of about 100 c. c. capacity, with cotton plugs, were sterilized in an autoclave 5 minutes at 15 pounds pressure.

26 of these bottles were filled with sea-water taken about 50 feet north of the beach-rock partly exposed at low tide, and a few hundred feet west of the laboratory dock.

25 bottles were filled with sea-water taken about 0.5 mile north of the laboratory dock, over beds of *Thalassia,* in water about 10 feet deep.

17 bottles were filled with water 4 miles from the laboratory dock, the water being several hundred feet deep at this station. Numerous "dust" particles floated on the surface of the water.

37 bottles were filled with water about 0.5 mile beyond station No. 3, where the surface film was of average clearness.

The bottles were carried to sea in a motor launch. At the stations specified the plugs were removed and the bottles dipped in the water. Some surface-film water was included in each bottle, but no attempt was made to get more of the surface film than would ordinarily run into a bottle while being filled with water in the upper 3 or 4 inches of surface water. The bottles were filled about three-quarters full and the plug replaced. The sea was quite calm on the day the water was collected and on the three preceding days.

After the bottles were brought to the laboratory a small piece of floating *Sargassum* (cooked for 5 minutes at 15 pounds pressure) was added to each bottle, with sterile forceps, and the plug replaced. (To 4 bottles of each of the 4 groups enumerated above, enough peptone was added to make the solution 0.1 per cent peptone.) The bottles were then set aside for 12 days in room temperature which varied from 35° to 40° C. during the day and at night from 28° to 33° C. At the end of this period about 3 c. c. were taken from each bottle with a sterilized pipette and placed in a sterilized watch-glass for microscopic examination. Amebas of the species *Flabellula mira* were found in small number in bottle No. 9 of group No. 3, and in large number in bottles Nos. 13 and 14 of the same group. These bottles did not contain peptone. No amebas of any species were observed in any of the other 101 bottles. The indication of this preliminary experiment is therefore that the surface water of the sea is sterile with respect to amebas, but that floating "dust" particles, and of course large pieces of floating *Sargassum* or other algæ, may carry amebas. In this experiment the dust-like particles floating on the surface undoubtedly carried the amebas which came up in the 3 bottles.

This result is not surprising. Amebas are relatively large organisms and in undisturbed water slowly sink to the bottom if unsupported by some floating object. Moreover, the researches of Professor Lipman show that the sea-water in the same region where this water was collected is very poor in bacteria, far too poor to afford sufficient food for the amebas. So that lack of a solid support and lack of food each by itself is sufficient to account for the absence of amebas from surface water. What the range of distribution of amebas is on the floor of the sea with respect to depth, texture, temperature, etc., is wholly unknown, but it is hoped that an investigation bearing on this point may soon be made.

Many species of amebas, however, do not eat bacteria, but require ciliates, flagellates, and especially diatoms and other small algæ of various kinds as food. In order to determine what the chief limiting factor is in the distribution of some of these species, the following preliminary experiment was set up:

It has long been known that the waters of the cooler oceans are much richer in plankton, especially in phytoplankton, than the waters of the tropical seas, and also that the cooler water contains considerably more nitrogen (about 3 parts per 1,000,000 of water) than the warmer water (about 1 part per 1,000,000). It has frequently been suggested that the difference in the amount of nitrogen accounts for the difference in the richness of the plankton. To test this point experimentally and to determine what effect a plentiful supply of food would have on amebas, I arranged a concrete tank 2.4 meters long by 35 cm. wide by 20 cm. deep. A few irregular concrete blocks, a couple of handfuls of coral sand, and a few pieces of *Sargassum* were thrown into the tank. A slow stream of water was run through the tank at the rate of about 100 liters per day. To the inflowing water was slowly added enough potassium nitrate in solution to make the sea-water in the tank about 1 part of nitrate to 100,000 parts of water. The tank was out in the open and was exposed to direct sunlight from 11 a. m. to 1^h 30^m p. m., but during the rest of the day it was partly shaded. On several days the temperature of the water at the bottom of the tank rose to 40° C. at the time of full exposure to the sun. The tank was set up on the seventh of June and a final examination was made on the first of July.

The number of diatoms in the tank increased enormously. In two weeks the floor and sides became brown with them. The appearance of these diatoms was quite different from those found in normal sea-water. The number of reserve food bodies (metachromatic bodies, volutin grains) in diatoms living in normal sea-water is usually 2, but the diatoms in the tank possessed from 10 to 20 or more of these bodies, and they were frequently connected with each other, forming an irregular, splotchy network. With these diatoms there came up the common marine ameba, *Mayorella conipes*, in large numbers. At the termination of the experiment it was found that every watch-glass full of fluid and sediment had a few dozen amebas in it. These amebas were of large size, of very clear protoplasm, with numerous clear crystals and a large number of reserve food bodies; some had one or more diatoms in them, but the great majority did not possess any recognizable food objects. The reserve food bodies were identical in appearance, but not in size or shape, with the reserve food bodies in the diatoms. More of these amebas were found in this culture than in any other that I have ever examined.

Near the end of the season it was realized that a control tank without potassium nitrate is necessary in order to learn by comparison exactly the effect of the nitrate. Lack of time preventing the setting up of such a control tank, I later staged a similar experiment at Cold Spring Harbor, New York, for the purpose of comparison from a different point of view. I set up a wooden tank of a size similar to the concrete tank mentioned above and ran a stream of water through it at the rate of about 100 liters a day, adding slowly enough potassium-nitrate solution to make the contents of the tank 1 part nitrate to 100,000 parts of sea-water. This tank was exposed to direct sunlight from early morning until about noon, when it was shaded by the laboratory building. In this tank also, which was under observation from July 20 until August 16, the diatoms increased enormously in number, covering the sides and bottom of the tank and the small stones in it with a thick, brownish, fuzzy coat. The number of reserve food bodies in the diatoms also increased greatly, up to several hundred in some of them, but the total amount of reserve food material was considerably less than in the diatoms in the tank at Tortugas. Some of the larger diatoms increased the amount of reserve food only two or three times over the normal amount. The overflow from this tank made a small pool in the quartz sand and this pool also became brown with diatoms. In this tank *Mayorella conipes* and *Trichamœba gumia* were found in small numbers. No ameba came up in large numbers.

No definite observations were made to determine whether the diatoms grown in these tanks possessed shells poorer in silica than those growing in normal sea-water. The very small amount of silica in sea-water has sometimes been considered as one of the most important limiting factors, if not the most important factor, in the growth and distribution of diatoms, and if this were true an excess of nitrate should not produce a marked increase in the rate of diatom growth. As we have seen, however, not only did the amount of reserve food material increase enormously in the individual diatom, but the number of diatoms themselves, and therefore the number of diatom shells, increased many times over the number usually present in sea-water.

These observations indicate, therefore, that the larger amount of nitrogen is actually responsible for a richer plankton in the cooler waters as compared with the warmer. It seems established, also, that an important limiting factor in the distribution of *Mayorella conipes*, and perhaps other species of amebas, is the food-supply. Similar experiments on a larger scale and for a longer time would probably show that the food-supply is the most important limiting factor under natural conditions controlling the distribution of amebas.

This method of changing the plankton constituents is very simple and must be of value in the investigation of the distribution and life cycles of many animals depending upon plankton organisms for food, especially mollusks and fish, not only in salt but also in fresh water. The low cost of nitrate makes it possible to perform such experiments on a large scale on natural bodies of water.

A study was made of floating *Sargassum* to determine to what extent the larger species of amebas (i. e., those that feed on organisms other than bacteria) are found on it. Floating *Sargassum* was collected at a number of stations several miles from Loggerhead Key, and then shaken with a small quantity of water to wash off the amebas and other animals clinging to it. In the sediment from the washings only one species of ameba was regularly present, *Trichamœba sphœrarum*, and it was found only in small number. These amebas are brilliantly colored on account of the endoplasmic inclusions. A large number of roundish bodies, some of brilliant orange, others of a bright-green color, were always present. The nature or origin of these bodies was not determined. I noted, however, that a large proportion of animals associated with *Sargassum*, including ciliates and flatworms, also contain large numbers of similar highly colored bodies. The *Trichamœba sphœrarum* of *Sargassum* is larger than that found growing in the surface ooze on muddy bottoms and differs somewhat in appearance from the latter. That both kinds belong to the same species is indicated, however, by the fact that they react in the same way to the various dilutions of sea-water; that is, they assume a spherical shape in 75 per cent sea-water and die in 50 per cent sea-water.

A Reconnaisance of the Vegetation of Tahiti, with Special Reference to that of the Reefs, by William Albert Setchell.

In pursuance of the plan to make a reconnaisance of the vegetation of the island of Tahiti, with special reference to the marine vegetation of the encircling reefs, headquarters were established at Papeete and maintained there from May 16 to July 19, 1922. My wife, Clara Ball Setchell, and Harold Ernest Parks, technical assistant in botany in the University of California, gave the utmost assistance in carrying out the details of the project. The lower levels of the main island were explored in large part, as well as a portion of both the east and west shores of the peninsula of Taiarapu. A hasty trip was undertaken to the adjacent island of Moorea for purposes of reef comparison. Certain of the reefs about Tahiti were selected as types and were investigated as intensively as time and facilities allowed. The land flora was collected and ecological conditions noted up to about 3,600 feet. Rock, soil, and coral samples were selected as bearing on the general and special problems and climatic data were assembled so far as recorded. The resulting notes and materials are considerable and will be worked over to supply the details necessary for the final report. A general sketch of the project may be presented, as follows:

The island of Tahiti consists of two distinct high land masses connected by a narrow, low isthmus. The larger mass, Tahiti Nui, or simply Tahiti, culminates in several sharp peaks, the highest of which, Orohena, is credited with being 7,321 feet in altitude. The smaller mass, Tahiti Iti, or the peninsula of Taiarapu, likewise culminates in several sharp peaks, the highest of which, Roniu, is credited as being 4,341 feet in altitude. Both Tahiti Nui and Taiarapu are much dissected and give evidence of having suffered tremendous and deep erosion, giving rise to deeply penetrating valleys with steep or even vertical walls, separated by high, narrow, even knifeblade-like ridges. Both land masses are more or less surrounded by a broader or narrower flat strand formation, interrupted here and there by the lower ridges descending to the ocean, and in several districts strongly cliffed. Both land masses are practically surrounded by reefs, fringing or barrier, awash or well submerged, but passes through the barrier reefs are numerous, allowing access to the shore either directly or by way of the broader or narrower, usually about 18 fathoms deep, lagoon moat. Rivers, some of considerable size and force of water, traverse the valleys, and the passes are fairly definitely situated relative to the more considerable débris-carrying rivers.

The reefs about Tahiti are both extensive and varied. A survey indicates at least six types, each bearing directly on the general as well as on the special problem of reef formation. The six reefs chosen for examination are: (1) incipient reefs at Tahara Mountain in the Arue district; (2) incipient reefs in the Papenu district; (3) exposed fringing reef at Arue in the Arue district; (4) combination reef at Atiue in the Punaauia district; (5) typical protected fringing reef at Auae near Papeete; and (6) the typical barrier reef outside Papeete Harbor.

Preliminary to reef study, an examination was made of the exposed outer point of Tahara Mountain and certain portions of the Papenu coast which are devoid of any conspicuous reef formation whatsoever.

Tahara Mountain terminates seaward in a bold bluff of volcanic agglomerate, much decomposed and traversed by broad anastomosing dikes. About the seaward face is a broad, flat shelf, a little above high-water mark, strongly cliffed above and below. The waves dash over it with violence at times of high water. The seaward cliff extends vertically downward for 4 to 5 fathoms and beyond it, about 0.75 mile, reaches 12 to 14 fathoms, beyond which, about a mile to the seaward, arises a submerged barrier reef to within 3 or 4 fathoms of the surface. Beyond the submerged barrier reef the coast slopes suddenly, reaching 100 fathoms in the distance of 3 miles from the point, whence the descent to 1,000 and more fathoms is abrupt. Studies at this point indicate the possible existence of two wave-benches, one in the neighborhood of the present sea-level and one submerged 20 to 30 fathoms.

There is indication of similar conditions along the Papenu coast. Much of this coast is of a coarsely columnar lava, at and below sea-level. There is some, but not positive, indication of a narrow wave-bench at 12 to 20 feet above sea-level, a narrow one at sea-level, and a broader or narrower one 20 to 30 fathoms below sea-level. The columnar structure of the rock of the cliffs, both above and below sea-level, has produced a bold and rugged coast, with nearly vertical cliffs, blow-holes, jagged rocks, etc.

The reefs practically surrounding the island may be distinguished into (1) submerged reefs or banks, (2) barrier reefs, (3) fringing reefs. In addition, there are isolated reef patches of larger or smaller size. The banks or submerged reefs occur off the coast, separated from it by a lagoon-like depression, and simulate true barrier reefs, except that they do not reach to tide-level. Their surface is 2 to 11 fathoms below it. It may be supposed that if undisturbed they may ultimately reach the surface and become true barrier reefs. They are to be found at the northeastern and the southeastern extremities of Tahiti and to a less degree on the northeastern coast of the Afaahite district. Their relation to full force of trade winds and consequently heavy seas is probably worthy of notice. Unfortunately, nothing could be determined as to their composition. They are probably largely nullipores (lithothamnia), but corals may enter more or less into their structure.

Barrier reefs, rising to the surface and having their rims awash at low-tide intervals, encircle the coast, except at the portions occupied by the banks or where they are separated by the passes. Unusually they are not over 0.25 mile, but in some cases, or portions of a reef, they may be 0.5 mile in width or a little over. The upper surface of the reef usually shows five more or less distinct belts or formations: (1) the outer nullipore belt, 250 to 300 feet across; (2) the *Sargassum* belt, 30 or many more feet across; (3) the *Turbinaria* belt, 15 or many more feet across; (4) the inner nullipore belt, 15 or more feet across; and (5) the innermost belt or coral rubble, coral mud, shells, etc., on which may grow a scattered assortment of living coral clumps, remotely or fairly closely placed.

The seaward edge of the reef descends in a steep slope to 18 to 25 fathoms, after which the descent is even steeper. Unfortunately, the waves pile in on the outer edge of the barrier reef, so that I know nothing of its structure. On the inner edge the reef descends almost vertically to 5 or more fathoms and then in a steep slope to 18 to 25 fathoms, the depth of the lagoon moat. This slope I have been able to study with the glass-bottomed boat of Messrs. R. I. and E. Walker of Papeete, and have observed that it is bare, with only an occasional clump of *Porites* or other massive coral. The lagoon moat varies from not much over 100 yards to a quarter of a mile in width and expands in places to 0.5 to 0.75 mile. The depth, as mentioned above, uniformly approximates 18 to 20 fathoms.

Fringing reefs present so many variations that it is necessary to classify them and to distinguish several types. Those on exposed shores are quite distinct from those on protected shores within the lagoon, and the former also vary somewhat among themselves in detail. I find it most satisfactory to discuss several of the exposed fringing reefs as examples of the variation existing among them.

The fringing reefs of exposed coasts selected for observation divide themselves naturally into two categories: (1) typical fringing reefs of small extent, not connected with barrier reefs in any way and lying within banks, or submerged reefs, farther out and separated from them by a deep depression comparable to a lagoon moat, and (2) combination fringing and barrier types of reef, but not separated from the land by a lagoon moat. Of the former category, three were selected for study and comparison, viz, those at Mount Tahara and Arue in the Arue district and one near Nivee in the Papenu district. Of the latter, the very interesting combination reef near Atiue in the Punaauia district was chosen.

The northwest point of Tahara Mountain projects, above and below sea-level, cliffed and bare of reef, showing only a fairly broad wave-bench beaten by the waves at times of high water. Around the point on the southwest side of the upper cliffs, a small, more or less triangular reef has been formed of beach-rock, made up of lava pebbles and sand, cemented together chiefly by the incrusting nullipores. From this conglomerate beach-rock the reef is extending seaward by a nullipore-coral rim forming a projecting shelf-like belt and followed shorewards by a *Sargassum* belt and by a *Turbinaria* belt of some width. These belts, and even the reefs farther in, are honeycombed below, so that the water spurts up from surface openings many yards in from the reef rim. This seems a good example of an incipient reef. It is the simplest reef observed in Tahiti.

The reefs along the "iron-bound" coast of Papenu near Nivee are similar to that of Tahara, but more extensive. They show the same construction of a beginning of beach-rock extended by an overhanging nullipore-coral rim. They have been formed in an area inclosed between projecting points of columnar lava-rock.

Out from the village of Arue is an isolated quadrangular reeflet and not far from the small triangular reef at Tahara Mountain. It projects from the midst of a beach of coarse sand, from which it is separated by a shallow, narrow channel. In structure and growth the Arue reef is like those at Tahara Mountain and Nivee. It is larger, not connected, so far as now visible, with any rock mass, and seemingly independent. It is bordered oceanward by a well-developed overhanging nullipore belt, within which is a *Sargassum* belt, a *Turbinaria* belt, a belt of short, fuzzy algæ, and finally the center is barren and broken up into irregular crests of lines of beach-lava pebbles incorporated within the reef-rock, forming a reef conglomerate.

These three reefs seem to have been built up by the cementing action of nullipores (lithothamnia) forming a core of pebbles, and sand, shells, and possibly even corals agglomerated together, and are now extending through the agency of the nullipores and corals. The outward face of these exposed incipient fringing reefs shows some resemblance to that of the barrier reefs, but the nullipore belt overhangs a steep slope in these reefs, while, on the barrier reef, the nullipore belt slopes gently both ways from the ridge-line and does not in any way overhang.

The barrier reefs of the coast of Tahiti are usually separated from the shore by a lagoon moat whose depth normally approaches 18 to 20 fathoms. The inner side of the lagoon moat is formed by a fringing reef (not of the exposed type), whose lagoon-moat side is vertical, at least above. In some cases the lagoon-moat, while yet distinct, is less than 18 fathoms, occasionally only 3 to 4 fathoms in depth. Sometimes there is no distinct lagoon-moat discernible, at least in spots, and there seems to be a fusion of fringing and barrier reefs. Such a case was examined near the village of Atiue, in the Punaauia district. The reef lies north of the pass which runs in toward the mouth of the Punaruu River. The outer portion of the reef is clearly barrier reef in its structure, with outer nullipore belt, *Sargassum* belt, and *Turbinaria* belt well developed and sloping gently outwards, but without overhang. This barrier portion of the reef is of coral and nullipore structure and is raised 2 feet or a little more above the reef flat within. The reef flat within is beach-rock, nullipore, sand, coral, and cobble structure, and extends inward to the shore with only a narrow, shallow channel running parallel to the shoreline. The edge of the inner reef towards the pass (south) is typical fringing reef, overhanging nullipore belt, and *Sargassum* and *Turbinaria* belts within that. The shore of the pass is of large cobbles pitched at a high angle and rolled about by the strong waves. The shore along the reef is of coarse sand. It may be surmised that the sand and cobble débris, cemented by the nullipore, has built up (and outward) the fringing reef to the point of fusing with the outer, probably originally distinct, barrier reef. Such fused reefs are most interesting in the study of the origin of both barrier and fringing reefs.

As an example of the inner or non-exposed fringing reef, bordering the lagoon moat, such as is general, the reef in the neighborhood of Auae, just west of Papeete, was chosen. The steep outer slopes were examined by aid of the glass-bottomed boat of Messrs. R. I. and E. Walker, while the surfaces, being covered with shallow water, were studied by wading over them. The outer face descends vertically for 6 to 9 fathoms and then slopes abruptly to from 12 to 18 fathoms. The surface of the reef is practically entirely of coral and the slope of coral mud. The reef flat is made up of coral mud nearer shore, then of coral rock and reef rock consolidated by thin crustaceous nullipores, but towards the outer edge shows living growth of various corals often densely aggregated, whose dying tips are also overgrown by a thin crust of nullipore.

Within the barrier reef, rising from the bottom of the lagoon, are larger or smaller reef patches, isolated, and with vertical walls. Their structure is very similar to that of the outer portion of the protected fringing reefs. The glass-bottomed boat allowed a very satisfactory survey of the fine collection of reef patches in Papeete Harbor.

The outer reefs, both barrier and bank, are separated from one another by passes, which bear a definite relation to the rivers, both in position and origin. The broader and more open passes are at the mouths of larger rivers, especially of those carrying coarser rock materials when in flood. Tracing down through the larger passes, a distinct channel may be demonstrated leading out to and somewhat beyond the reef edge, a channel probably cut through the older wave-bench (or fringing reef?) when the sea stood at a lower level (about 20 to 30 fathoms) than it does at present and kept open by the erosive action of the débris since that time. Even when larger, but less erosive, rivers have their mouths inclosed by reefs, there may be indentations indicating the existence of a former pass, now more or less closed. Typical examples of such indentations of the barrier reef may be seen opposite the Oahu and Terechia Rivers in the Papara district, an almost closed pass opposite the river emptying by Patere in the same district, and many others. Of the passes between the banks, the Papenu Pass opposite the river of that name is an excellent example.

A study of the passes, therefore, seems to indicate that they are kept open by erosion caused by the river débris (cobbles and sand) and, although many are now closed, that they exist along depressions caused by the same agencies when the sea-level was much lower than at present.

Tahiti Nui is a much eroded, complicated cone with a deep egg-shaped valley occupying its very center and opening out towards the north. From the interrupted curved ridge surrounding the inner portion of this valley (Papenu Valley) arise a number of the higher peaks, and ridges descend thence to the coast. Between and among these ridges are gullies and deeper valleys, each eroded by the stream which it incloses. Around the base of the cone is a broader or narrower flat shelf, or coastal plain, which (alone) is inhabited and cultivated. Taiarapu shows a single slightly curved ridge running lengthwise of the peninsula and somewhat nearer the southwest coast, from which a few ridges run out almost at right angles. Our reconnaisance was almost entirely confined to Tahiti Nui and to the lower slopes (up to about 3,600 feet). The highest peak is Orohena, 7,321 feet, but Aorai, 6,773 feet, shares its prominence. There are to be distinguished three belts, the strand belt (coastal plain or "zone madreporique"), the slopes up to about 5,500 feet, and the extreme summits of Aorai and Orohena. Each of these belts presents a series of distinct formations.

The strand belt is flat and not much over two-thirds of a mile wide at any point, usually not much over 100 yards in width, and at various points is lacking altogether. It is evidently of alluvial origin, sand, pebbles, and humus in various admixtures, probably about 18 feet thick or somewhat over, but investigation as to details is needed. In the great valley of the Papenu River there is a sort of extension of it into the interior of the island, but elsewhere it is strictly coastal. The soil is shallow and overlies rock, either a lava bench or more commonly beach-rock of a buried fringing reef at about the level of the sea. The strand trees are those usual in western Polynesia, but some of these are now very scarce. The cultural plants, such as the coconut, sugar-cane, banana, coffee, and vanilla, are largely confined to this belt. The Chinese vegetable gardens are here, largely on drained swampy lands. The villages are all on this belt, although in earlier times some fair proportion of the population occupied the valley slope up to 2,000 feet altitude. The only conspicuous endemic species on this belt is the Tahitian banyan (*Ficus prolixa* Forst.), but this whole belt is now overrun with tropical weeds, many of them of comparatively recent introduction. Of these, the members of the Leguminosæ are by far most frequent, but several Convolvulaceæ and a few Compositæ and Labiatæ occur. The principal formations are cultural, strand, swamp, and thicket, but there are no mangrove associations on Tahiti. On its inner edges this belt meets the cliffs and steep slopes of the older shoreline which mark the beginning of the lower slope belt.

The lower slope belt is varied into ridge and valley formations of various kinds. The slope formations are fairly uniform and cover poor, shallow, dry soil, formed in position from decomposed soft volcanic rock. The characteristic association is fern thicket, composed largely of *Dicranopteris linearis*, which covers large areas from base to upper limits. This is mixed with shrubs, or occasionally trees, of *Dodonæa viscosa* and *Metrosideros collinum*, but more recently invaded by lantana, guava, and *Tecoma stans*. The characteristic ridges and exposed slopes from base to the upper slope belt are often covered with dense and almost impenetrable thickets of these species. Among the fern thickets, especially higher up, are found scattered, and often extensive, patches of the "native sugar-cane."

The valley formations consist of shallower gullies or the deeper river valleys, or, in short, of gullies and valleys. The gullies occurring at middle or higher elevations often show no difference from the ridge slopes when shallower and drier, but when deeper and moist are occupied by a scanty or even a most abundant growth of trees, usually with the candle-nut (*Aleurites moluccana*) dominant above, or with the Polynesian chestnut (*Inocarpus edulis*) mixed with the candle-nut.

The valley formations vary according to the slope and composition of their sides. The lower valleys often show *Inocarpus, Aleurites, Cerbera,* etc., mixed with ferns and epiphytes. Farther up may be found mara (*Neonauclea forsteriana*), and in the upper reaches of moist cliff or talus slopes with fair quantity of soil, pu'a (*Fagrœa berteriana*), *Homalanthus, Laportea, Nothopanax,* fehi in associations of its own, and special floras for each particular valley. The general indicators for such an indigenous valley flora are the tree-ferns (*Cyathea* sp. and *Angiopteris evecta*). These descend almost to sea-level in moist valleys and wet exposures on the northeast and southeast coasts, but do not descend below 1,000 to 1,500 feet on the drier coasts, e. g., in the Pare and Punaauia districts. Much of the peculiar flora of Tahiti is to be found on the cliffs and upper talus slopes of the valleys of this belt.

The higher slopes and summits are also diversified, but particularly into the dry exposed slopes and the drier or moister cliffs. On the exposed dry slopes the fern association (*Dicranopteris*) gives way to low thickets of *Lycopodium cernuum* and its associates. On the uppermost valleys and on moist cliffs are found many of the most characteristic endemic species, such as arboreal Compositæ and Lobelioideæ, although some of these descend much lower.

In making a reconnaisance of the flora of Tahiti, one thing becomes early evident, and that is the tremendous changes that have taken place since the island was discovered, and particularly in recent years. A brief visit to Moorea, where fewer changes have occurred, made this even more apparent. These changes are most noticeable on the coastal plain, but even in the lower slope belt much has been done and the work of driving out and upward the indigenous species is still actively going on. The birds have suffered severely also, and many or most of the original species are all but extinct. Species of plants of tropical origin introduced either into cultivation or as weeds thrive amazingly under Tahitian conditions and soon escape or spread and occupy large areas, to the exclusion of other plants, especially of indigenous species.

The weeds of wayside and field grow in astonishing profusion and are only slightly held in check, even with great effort. The ornamentals spread far beyond the places of cultivation. There are three species which have affected the flora of the slopes materially, and these are the lantana, the guava, and the yellow trumpet-flower (*Tecoma stans*). This last has, through its buoyant winged seeds being carried by the upward currents of air, invaded even the highest slopes.

Another series of changes has come about through the using up of trees available for purposes of fuel and construction. The tou (*Cordia subcordata*), the tia nina (*Hernandia peltata*), and the atæ (*Erythrina indica*) have all but disappeared and canoe trees like the mara (*Neonauclea forsteriana*) are becoming scarcer lower down. Even the fehi, once so abundant and plucked with care, must be sought in more and more inaccessible places, especially since the decline in productivity of the vanilla plant has compelled a return of the native to his primitive foodstuffs. Of smaller plants, I have sought *Cardamine sarmentosa* and *Lepidium piscidium* in vain where once they were presumably abundant. The purau (*Hibiscus tiliaceus*), however, seems on the increase and is advancing up the valleys to the exclusion of other native plants. *Freycinetia victoriperrea* Solms is increasing in the fehi formations and is crowding out this valuable native food-plant. *Typha latifolia* has seemingly invaded tide flats and wet marshes in many localities, and the water hyacinth (*Eichhornia crassipes*) forms floating masses in many tidal streams.

Studies of Fossils from Walu Bay, Fiji; corals and Bottom Samples from Pago Pago Harbor, Samoa; and Bottom Samples from the Bahamas and Florida, by Thomas Wayland Vaughan.

Dr. Mayor referred to me for study and report three sets of collections made by him in the course of his investigations in the Fiji and Samoan Islands, as follows: Fossils from Walu Bay, Viti Levu, Fiji Islands; corals from Pago Pago Harbor, Samoa; and bottom samples from Pago Pago Harbor, Samoa. Besides the studies on these collections, much additional work has recently been done on the bottom samples collected in the Bahamas and Florida as part of the investigations I undertook in connection with the Department of Marine Biology. The present report gives a brief statement of the status of the investigation of the collections above mentioned.

Fossils from Walu Bay, Viti Levu, Fiji Islands.

The rather small, but important, collections made in the quarries on Walu Bay by Doctor Mayor and Mr. Coleman C. Wall, and an earlier collection made by the U. S. Bureau of Fisheries steamer *Albatross*, have been studied by Mr. W. C. Mansfield, palæontologist of the U. S. Geological Survey, who has written a report on them and an annotated bibliography of the geology of the Fiji Islands. I have in preparation an article on the stratigraphic succession and probable age of the sedimentary formations of the Fiji Islands, which is intended to accompany Mr. Mansfield's report.

It may be remarked that the existence of deposits of Miocene age on the island of Mango is indicated by the presence there of a species of *Lepidocyclina* identified by F. Chapman as *L. sumatrensis* (Brady). It is interesting to compare this determination with the recently reported occurrence of a species of *Lepidocyclina*, which belongs in the group of *L. morgani* Lem. and R. Douvillé, in the reef conglomerate of Jaluit, Marshall Islands.[1] The presence of teeth of the shark *Charcharodon megalodon* Agassiz, as well as the fossil mollusks, in the quarries at Walu Bay, Viti Levu, indicates that the rocks there exposed are probably of late Miocene, possibly Pliocene, age. The "soapstone" which underlies these deposits, but grades into them, would, therefore, be a little older, notwithstanding H. B. Brady's opinion that "there need not be * * * the slightest hesitation in assuming the Post-Tertiary origin of the deposits."[2]

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[1] H. Yabe, and R Aoki: Reef conglomerate with small pellets of *Lepidocyclina* limestone found on the Atoll Jaluit. Japanese Jour. Geol. and Geograph., vol. 1, pp. 39–43, pl. 4, 1922.

[2] H. B. Brady, Note on the so-called "soapstone" of Fiji. Geol. Soc. London Quart. Jour., vol. 44, pp. 1–10, pl., 1888.

Brady's study of the Foraminifera in the "soapstone" at Suva is of interest for comparison with the report on the organisms found in the Funafuti boring.[1] The lower part of the Funafuti boring might be of Tertiary age. The chemical nature of the material obtained in the bore indicates, as F. W. Clarke has pointed out,[2] two different formations beneath the surface layer.

Disregarding the problematic age of the lower part of the Funafuti bore, there is a gradually increasing body of evidence that sedimentary deposits of Tertiary age, Miocene to Pliocene, are widely distributed in Oceania, and that they occur both in such islands as the Fijis, which are believed to be remnants of a former continental mass, and in the truly oceanic islands. It seems that changes in altitude of some at least of the oceanic islands have been less during Recent geologic times than supposed by some geologists.

Corals from Pago Pago Harbor, Samoa.

With the approval of Dr. Mayor, an arrangement was made with Mr. J. Edward Hoffmeister, a graduate student in geology in Johns Hopkins University, to study and prepare a report, under my direction, on the corals collected by Dr. Mayor in Samoa. Prior to this arrangement I had examined a part of the collection and had given Dr. Mayor a provisional list of a considerable number of the species. The number of species in the collection is estimated to be between 45 and 60, of which Mr. Hoffmeister has already studied 16 species belonging to the genera *Pocillopora*, *Leptastrea*, *Galaxea*, *Orbicella*, *Favia*, *Favites*, and *Leptoria*. Mr. Hoffmeister resumed work on the collection about the middle of September (1922) and hopes to complete the report by the summer of 1923.

This is a valuable collection for three reasons: (1) it represents an area the coral fauna of which is inadequately known; (2) it is as nearly complete as in reason may be expected, and therefore really gives an adequate idea of the composition of the fauna; and (3) every specimen in the collection was taken with careful attention to its environmental conditions. The report on this collection will, therefore, constitute an important addition to knowledge of the geographic distribution and ecologic relations of modern coral faunas.

Bottom Samples from Pago Pago Harbor, Samoa.

When Dr. Mayor first sent me the bottom samples collected in Pago Pago Harbor I hoped to study them personally, but pressure of other work prevented my doing that. It was therefore necessary to make other provisions and Mr. M. N. Bramlette, of the U. S. Geological Survey, was engaged to examine and report on the samples. The mechanical analyses were made by the Bureau of Soils, U. S. Department of Agriculture, and the chemical analyses were made by Mr. L. G. Fairchild, of the Chemical Laboratory of the U. S. Geological Survey. Without this assistance proper study of the samples and the preparation of a report would not have been possible.

On May 1, 1922, Mr. Bramlette had completed the examination of 18 of the 28 samples submitted and the mechanical analyses for all 28 had been finished. Two type samples had been studied in detail, following the procedure of Goldman in his study of two samples from Murray Island, Australia.[3] The other samples were not studied in so great detail. Mr. Bramlette resumed work on the collection during the latter part of July. This work will constitute the first critical study of the shoal-water bottom deposits in an embayment in a tropical island and will be valuable for comparison with the studies made by the Royal Society coral-reef expedition to Funafuti, the studies made of the deposits associated with the coral reef at Murray Island, Australia, and the studies of the shoal-water deposits of the Bahamas and Florida. Accurate knowledge of the shoal-water deposits in several parts of the tropical seas is now becoming considerable.

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[1] G. J. Hinde, Report on the materials from the borings at the Funafuti Atoll. The Atoll of Funafuti, Royal Society of London, pp. 186-360, 1904.

[2] F. W. Clarke and W. C. Wheeler, The inoganic constituents of marine invertebrates and calcareous algæ. U. S. Geol. Survey Prof. Pap. 102, p. 53, 1917.

[3] Carnegie Inst. Wash. Pub. 213, pp. 249-262, 1918.

Bottom Samples from the Bahamas and Florida.

In consequence of interruptions due to the Great War and other causes, the studies of the bottom samples I collected in association with the Department of Marine Biology in the Bahamas and Florida betwen 1912 and 1915 suffered postponement and but little was done on the samples between 1916 and the summer of 1921, when the studies were resumed. An effort is being made to complete certain supplemental studies and to present in form suitable for publication the entire body of information. Considerable information on the Bahamian and Floridian bottom deposits has been given in publication No. 213 of the Carnegie Institution, in other publications of the Institution, and elsewhere, but the statements therein contained are only preliminary accounts of the work. For instance, the results of only a small fraction of the mechanical analyses have been printed.

During the past year, Dr. M. I. Goldman, of the U. S. Geological Survey, has completed an exhaustive study of the ingredients of a composite sample of reef sand from behind Coconut Point reef, Andros Island, Bahamas. In 1921, Dr. Paul Bartsch collected for me an additional sample of calcium-carbonate mud off the west side of Andros Island, while on an expedition under the auspices of the Department of Marine Biology. This sample has been elaborately studied in a number of different ways. A complete chemical analysis and a special chemical analysis for organic carbon have been made by Mr. E. T. Erickson in the Chemical Laboratory of the U. S. Geological Survey; Professor Milton Whitney, chief of the Bureau of Soils, U. S. Department of Agriculture, has supervised mechanical analyses and tests for colloidal material by the amount of water-vapor absorbed; Dr. K. F. Kellerman of the Bureau of Plant Industry, U. S. Department of Agriculture, has studied the bacterial flora of this sample and has conducted experiments to ascertain if certain bacteria will precipitate calcium carbonate when grown on no culture medium except the bottom mud; and I have devoted much time to a study of the ingredients composing the sample. Dr. R. C. Wells, of the U. S. Geological Survey, is conducting a series of experiments on the cementation of calcium-carbonate sands. Much other work has been done, but the details will not be given here, enough having been said to indicate the progress made in the investigations.

The purpose of these investigations is to aid in understanding the origin, the classification, and the lithification of limestones, and already important results have been achieved. A point worth noting is that chemical analyses and determinations of the percentages of material in the colloidal state have recently been completed for about 60 deep-sea samples collected from the latitude of the north end of the Bahamas, off the Bahamas, across the Caribbean Sea from Jamaica to Panama, and off the southwest coast of Central America to off the southern end of Lower California. These samples show a gradual decrease in the percentage of $CaCO_3$, and inversely an increase in the percentage of material in a colloidal state from the shores of the Bahamas to the deep sea. In the shallow-water samples in the Bahamas the percentage of $CaCO_3$ ranges from 93 to 97, where there is no undue concentration of $MgCO_3$, and in the Tongue of the Ocean at depths of 800 to 825 fathoms there is between 95 and 96 per cent $CaCO_3$. The following are the percentages of $CaCO_3$ and colloidal material in deep-sea samples from off the Bahamas:

No. of sample.	Depth.	Temp.	$CaCO_3$.[1]	Colloid.[2]
	fathoms.	*°C.*	*p. ct.*	*p. ct.*
6	2,534	2.8	40.20	57.8
7	2,758	2.7	38.02	46.8
8	2,655	2 8	33.45	48.6
9	2,595	2.0	38.42	43.5

[1] Analyses by L. G. Fairchild.

[2] Determination by U. S. Bureau of Soils. Method used, absorption of water-vapor.

From the data at present available, the inference seems warranted that a very high percentage of $CaCO_3$ in a limestone indicates a shallow-water or only a moderately deep-water deposit. Such relations as those stated above illustrate the nature of the results from a comparison of the Bahamian and Floridian bottom deposits with marine deposits formed under other conditions.

DEPARTMENT OF MERIDIAN ASTROMETRY.[1]

BENJAMIN BOSS, DIRECTOR.

The present report covers the activities of the Department of Meridian Astrometry during the year September 1, 1921, to August 31, 1922. Special attention has been devoted to a development of the treatment of differential refraction as it applies to the work of the Department. While the preliminary steps in the reduction of observations are not affected by the introduction of corrections for differential refraction, the later treatment must be revised if we are to gain the full value of the material with which we are dealing, and if we are to develop the opportunity for a study of some of the basic principles of positional astronomy. A large field of activity has been opened.

DIFFERENTIAL REFRACTION.

The history of meridian astrometry has been punctuated by successive discoveries which, through the removal of sources of error, have lent refinement to the observations. Sometimes we have been aware of the presence of outstanding peculiarities in observations, but, through inability to fit the causes, we have attributed them to accidental error or to some professedly unknown cause, and have introduced arbitrary corrections in an attempt to harmonize the results. Thus for a long time it has been recognized that a distinct difference exists between daytime and night observations. It has been the habit either to reject daytime observations or to correct them to fit the night observations.

Eventually it developed that where the corrections to the clock, as derived from observations of the stars, were arranged according to the time of day, a progressive change was taking place. This at first was attributed to variation in the clock-rate, but it appeared to us that the fact that clocks running under entirely different conditions behaved in the same way discredited the possibility of variation of rate. It was likewise difficult to attribute the change of rate to any known cause. It seemed far more probable that a diurnal effect in the observations was caused by the known diurnal changes in the atmosphere. In addition, testimony has been accumulating to show that similar diurnal effects are inherent in observations in zenith-distance. It therefore seemed reasonable to expect that the same cause was affecting the observations in both coordinates.

In the report of this Department, in the Year Book for 1921, the results of some preliminary experiments by Mr. Varnum were given. These experiments have been continued and amplified.

In dealing with the reduction of meridian observations it has been assumed that the strata of air lie parallel with the earth's surface. The refraction tables are computed on this basis. As a matter of fact, the strata generally will be inclined toward the earth's surface, producing a prismatic effect which tends to shift the positions of the stars bodily, and to affect both right-ascension and declination according to the tilt in the air strata. Heretofore the material has not been available for a study of possible shifts due to varying conditions of the air, but the observations taken at San Luis and at Albany were planned in a manner to cover all probable contingencies, as far as possible. Thus, when certain peculiarities became evident during the course of the reduction of the observations, an effort was made to trace them to their cause, and various considerations led to an investigation of atmospheric effects. In the first place, a correction to the constant of refraction is introduced for zenith-distances. To this is added a differential term.

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[1] Address: Dudley Observatory, Albany, New York.

The question next arose as to the connection between the observational peculiarities noted and the differential refraction as represented by the deduced formulæ. Observation had shown a diurnal effect. This might correspond to diurnal changes in barometer, thermometer, and hygrometer, but, from observation it appears that the temperature and not the barometer is the controlling factor in producing changes. The records of the shade thermometer had necessarily to be used at first.

Assuming the *Pulkova Refraction Tables* as a standard of reference, the relative refraction and the rate of change can be obtained for the period of observation. The sum of the products of these quantities into the differential of refraction form the equation representing the shifting conditions of the atmosphere.

Proceeding with these equations, certain series of observations, chosen at random, were treated for differential refraction and the results were very satisfactory. There is an unmistakable connection between differential refraction and the peculiar observational results. By employing the derived corrections, observations taken at all times of day are brought into better harmony.

The effects we are dealing with are more dependent upon sun temperature and humidity than upon shade temperature, but no records of sun temperature and humidity were available, and we therefore resorted to a Fourier series which represents the changes. Thus we are not only taking into account surface effects, but are integrating the conditions of atmosphere from the earth's surface outward. Using a Fourier series, the accordance between observations taken at all times of day is greatly improved. Thus it is shown that differential refraction explains the apparent irregularity of the clock. It also accounts for the effect between night and day observations. But, perhaps more important than all, it helps to straighten the lines of reference from which we reckon star positions. It will also have an influence upon the variation of latitude.

It is important that future programs of meridian observations be arranged with a view to determining the shift in the positions of stars dependent upon atmospheric conditions, and this can not be properly tested unless the observations are taken in a strictly fundamental way. While the theory is fully understood, observational programs in the past have not been arranged in a manner to obtain truly fundamental results. The very basic principles are often lost sight of. Therefore, it may be in order to restate them.

FUNDAMENTAL OBSERVATIONS.

It is absolutely necessary to observe successive culminations of polar stars. In dealing with right-ascensions we determine the time of transit across a vertical plane passing through the pole. There is only one way to locate the pole, fundamentally speaking, and that is through successive culminations of the same circumpolar star. Likewise with declinations. Declinations are determined by combining the circle reading at the pole with that on the star;

but the circle reading at the pole can be formed only from the circle readings on one and the same circumpolar star at both culminations. Because of personal error, the same observer should observe both successive culminations.

For right-ascensions we also need to observe time stars 12 hours apart and a certain number of stars at successive transits to give the error and rate of the clock, which is the measuring rod in this coordinate. It would also be a distinct advantage to have groups of time stars 6 hours apart. In declination the measuring-rod is the graduated circle, whose errors can be determined.

Because of the instability of the instrument, some fixed direction of reference should be had, observable at any time, so that not only the observations of circumpolar stars may be compared, but that the result may be compared with the observations of the other stars whose positions are to be determined. In right-ascension the mire mark is usually taken, in declination the nadir. The only requirement is that the instrument shall be corrected by means of a particular, unchanging position. The nadir is fixed by the earth's unvarying attraction, but possible movement in the mire mark must be investigated.

The above is very elementary theory. Observations are subject to a variety of errors. Because the fundamental determinations necessarily hinge upon a pair of observations made 12 hours apart, especial attention must be devoted to those sources of error which vary with the daily meteorological rhythm, and this elimination should begin at the earliest practicable stage in the reductions.

Such are the terms in differential refraction. The mean of the circle readings at two culminations is roughly the circle reading at the pole, but it does not correspond to either time of observation, but to a time when differential refraction is nearly zero. Similar considerations apply to the observations in right-ascension. Even if fundamental methods are used, the reduced places will, if these corrections be omitted, contain many anomalies. These anomalies are in the San Luis and Albany observations, lying in great blocks, plus and minus, in both right-ascension and declination. If they are left so, a large part of the possible precision is lost, to say nothing of very probable systematic errors, due to the fact that evening observations are most numerous. If they are apparently eliminated by breaking the work into short pieces, each of which is corrected separately, they are not really removed; their effect remains, though hidden. Such a proceeding can either change the system of the observations, as approximately reduced, or it can not. If it can not, there is no gain in systematic value; all the errors of a systematic character produced by the uncorrected errors remain. The only effect is to smooth off individual divergences from the preliminary system. On the other hand, if it can, there is still no guaranty that the change is even in the right direction.

The attempt should be made to link these anomalies to their cause, or to some concomitantly varying effect of the same cause. The differential refraction term does this for a large part of them. It should therefore be included, and at the most appropriate stage in the reductions, which is at the point when the two observations of the circumpolar star are brought together. In the right-ascensions it can be introduced at a somewhat later stage, since the error made in azimuth can be included in the formula.

It is not to be supposed that this will produce perfect results. The variation of differential refraction with observed meteorology is, though fair, not absolute. Difficulties of this sort inhere in any series of observations. Moreover, there will be anomalies due to wholly different causes. Such will be hopelessly disguised by any ironing-out process; but by systematically removing one anomaly the others will stand out more clearly.

This in itself is cause sufficient for removing the differential refraction effects from observations, but there are further developments of great importance.

DEVELOPMENTS FROM DIFFERENTIAL REFRACTION.

Reference is made to the various astronomical constants, to variation of latitude, and more especially to the law of refraction. The last has been studied many times, with results which do not carry us far beyond the point reached by Bessel in his *Fundamenta Astronomica* about a century ago. The reason is that, already in his day, the study of refraction had gone about as far as it could by the method of averaging results and hoping that anomaly would balance anomaly. Further progress can result only from a study of these anomalies themselves. Their removal will clear the way, we may reasonably hope, to further progress with the law of refraction itself.

The study of most of the astronomical constants, so called, and of the variation of latitudes, has been hitherto made upon the basis of differential observations especially designed for the purpose. The possibility of something having been overlooked in such studies, which might make their results not strictly applicable to observations made under routine meridian-circle conditions, has never been sufficiently considered.

Through a revision of our reductions of the observations, on the basis of inclusion of the differential refraction term, we hope to reap the benefits delineated above. The combination of observations taken north and south of the equator with the same instrument, and largely with the same observers, offers a special opportunity for the study of the fundamental laws of refraction and for the establishment of a more perfect system of star positions stretching from pole to pole. This in turn will help materially in improving the proper-motions of the stars.

It is well to stress a few points which should be carefully considered in all fundamental meridian programs of the future.

1. Circumpolar stars must be observed at successive culminations. For the sake of continuity, and to avoid personal equation, the same observer should continue his observations over that period of time. (According to our practice at Albany, the same observer is on duty for the period of a week.)

2. Time stars should be observed 12 hours apart, preferably 6 hours apart, and successive transits of the same time star should be taken. Again all these observations should be taken by the same observer.

3. Daylight as well as night observations should be taken, some in the morning and some in the afternoon. Zenith-distances as well as transits of these stars should be observed.

4. Sun-temperature and humidity records should be included hereafter, as the effects of differential refraction seem to respond to these two elements.

REDUCTIONS OF OBSERVATIONS.

When the reduction of the Albany zenith-distance observations, under the supervision of Mr. Roy, was suspended in March, pending the results to be derived from the study of differential refraction, the computations were in an advanced stage. Many of the least-square solutions for the final equator-point and refraction correction had been made and the normal equations for the remainder were ready for solution. The critical examination to determine which series needed a revision of the rate in the equator-point as given by the nadirs was well started.

In the preliminary reductions it was assumed that the minor variations of the refraction constant could be ignored, but it developed that there were marked changes, sometimes within a short period of time. The tremendous changes in the refraction constant, under weather conditions outwardly fairly uniform, are illustrated by 3 days in May 1916.

Refraction factors.	Late p. m.	Early night.
May 11....	9.9963	1.0091
12....	9.9976	1.0058
13....	1.0046	1.0044

An assumption that the refraction constant has a uniform daily variation or that it remains constant for many hours at a time would do violence to the observations.

The San Luis zenith-distance observations are completely reduced. The means in declination have been formed as far as 7 hours 43 minutes, the formation being suspended in March. The secular variations have been checked in both coordinates.

An attempt was made to determine the correction to the refraction constant from the San Luis circumpolar observations. A correction to the latitude of $-0''.51$ was obtained, and the correction to the refraction constant was $+0''.31$. When the material was collected according to groups of stars in each degree great anomalies appeared. The results show the necessity of modifying the Pulkova refraction tables to fit a particular station when attempting fundamental work.

THE PROPER-MOTIONS OF 154 RED STARS.

Due to their faintness, coupled in general with magnitude variation, the red stars, Classes Md, N, and R, have been neglected by meridian observers and proper-motions of but a few of them have been available to students of stellar motions. In view of their peculiar relations to the sequence of stellar evolution, it is important that as much information as we can secure with regard to their motions be made available. In the *Astronomical Journal*, No. 796, Dr. Wilson published proper-motions of 154 of these stars. From an analysis of the data given therein the following conclusions were reached:

1. The proper-motions of the Class M stars are in general small, their velocities in the line of sight are large; apparently, therefore, their real motions are large, they are very distant, and the majority of the stars of this class whose proper-motions are known must be giants.

2. The proper-motions of the Class N stars are systematically small; their radial motions so far as known are small; they must as a class, therefore, be numbered among the more slowly moving members of the stellar system.

3. The direction of the solar motion derived from the red stars agrees well with that derived from the stars of other spectral classes.

4. The red stars follow the general tendency of the other stars in preferential motions towards Kapteyn's vertex.

Since the publication of this investigation a great deal more material has become available, especially in Gyllenberg's observations of 391 of these stars (*Meddelanden fran Lunds Astronomiska Observatorium*, Series II, vol. 32, No. 11), and a complete reinvestigation of the material has been carried through. From this study the proper-motions of 312 red stars have been derived. An analysis of these motions in now under way.

STELLAR WAVE-LENGTHS.

The study of wave-lengths in stellar spectra was continued by Dr. Albrecht. Wave-lengths were determined for the Class B8 star *c* Carinæ. The publication of these wave-lengths is being delayed temporarily in the expectation that it may shortly be possible to more nearly complete their identification with laboratory results.

Detailed study of Class B stars gives promise of contributing very important results toward the problem of the constitution of matter. It is well known that the lines present or measurable in these types change very markedly with minor changes in type. Thus, the published measures of the Yerkes and Lick Observatories indicate that Class B8 is differentiated from Class B5 by the rather abrupt appearance of a considerable number of metallic lines and the practical disappearance of the oxygen and nitrogen lines, and from Class A by a pronounced falling off in the number of metallic lines. The silicon lines increase from B0 to B1 or B2 and then gradually fade out toward B8, while the magnesium line 4481.4 is very faint in the early B-types and becomes very prominent in B8. The metallic lines involved are the so-called "enhanced lines." The importance of Class B8, which is, as it were, a transition stage for the enhanced lines, has been materially increased by the recent advances in the theory of ionization.

The K-term, which has been attributed to various causes, including the Einstein effect, has been shown to be due, at least in part, to the use of inaccurate normal wave-lengths in the radial velocity determinations. In the June number of the *Astrophysical Journal* it was shown that recent laboratory wave-lengths for twenty oxygen and nitrogen lines occurring in B-type stars are systematically 0.063 A longer than the adopted normals. This corresponds to a change of −4.2 km. in the radial velocities derived from them. A discussion of the available portions of the data on which the K-term is based indicates that the new wave-lengths for this one group of lines alone would reduce the K-term, which is about 4 km., by about 0.3 km. for the entire B class and by about 0.8 km. for classes B0 to B2. In a second article, which is practically ready for publication, it will be shown that new laboratory wave-lengths by Crookes for silicon lines and a new wave-length for the helium line 4713 by Merrill still further reduce the K-term by about 1 km. for the entire B class and by about 2 km. for classes B0 to B2. Moreover, it is pointed out that the lines upon which necessarily most emphasis has been placed in radial-velocity determinations, namely, Carbon 4267, Hγ 4340, Mg 4481, and the four helium lines in the region used, are double, with unequal components, and therefore not suited for primary radial velocity work.

STAFF.

The Director has been engaged on investigations in statistical fields and has likewise devoted some study to the question of differential refraction as it affects the observations in process of reduction and for future development of the subject. Dr. Sebastian Albrecht continued his researches on standards of wave-length. Mr. Sherwood B. Grant and Mr. Heroy Jenkins have assisted in the general work. The efforts of Mr. Harry Raymond have covered all departments of our activities. Mr. Arthur J. Roy supervised the reduction of zenith-distances until March, since when he has been engaged on special tests of the observations. Mr. William B. Varnum has devoted his time to the study of differential refraction and to preparation of the observations for the inclusion of this correction. Dr. Ralph E. Wilson has made a study of the red stars and in addition has collaborated with Mr. Varnum. Miss Alice M. Fuller has continued as secretary of the Department.

The energies of the computing staff have mainly been confined to computations arising from the detection of the effect of differential refraction in the observations. It has consisted of Miss Marion F. Benjamin, Mrs. Lillian F. Blanchard, Miss Grace I. Buffum, Mrs. Livia C. Clark, Miss Grace Cramer, Miss Isabella Lange, Miss Marie Lange, Miss Mary M. Kampf, and Miss Frances L. MacNeill. In addition there have been three temporary computers.

MOUNT WILSON OBSERVATORY.[1]

George E. Hale, Director.
Walter S. Adams, Assistant Director.

SUMMARY OF THE YEAR'S WORK.

It is a satisfaction to report that the exceptional progress in research recorded last year has shown no sign of abatement. Its future continuation, sufficiently assured by the productive vigor of the Observatory staff, will be further promoted by the establishment of close and effective cooperation with the California Institute of Technology and by the initiation of promising new enterprises, some of which involve important additions to our instrumental equipment. In epitomizing the year's advances, special mention should be made of Seares's researches on the masses of the stars and on the progressive changes of temperature, diameter, and density that mark the course of stellar evolution; the discovery by Strömberg of the identity of the two star-streams found by Kapteyn among the A-type stars with the Taurus and the Ursa Major groups, and of the marked difference in stream-motion of the giants and dwarfs of the later spectral types; the development by Adams and Joy of a spectroscopic method of measuring the absolute magnitude (and hence the distances) of the white (A) stars, and its immediate application to 544 of these objects; the theoretical investigations of Russell on the nature of dark nebulæ; the proof by Hubble that the radiation of the nebulæ is stimulated by stars lying within them; the discovery by Nicholson and Pettit that the total radiation of certain red variables of the eighth magnitude is as great as that of white stars of the second magnitude; the measurement by Abbot of the energy distribution in the spectra of certain of the brighter stars and the promise this work yields of great advances in this important field of investigation; the progress made by Michelson in the redetermination of the velocity of light and his contributions to other important physical problems; the detection of invisible sun-spots by their Zeeman effect; the important contributions made by St. John and Babcock toward the establishment of the system of standards of arc wave-lengths now internationally adopted, their measurements of solar lines and the continuation of their investigations of the causes giving rise to the displacements of lines in the sun; the proof by Anderson that an electrically exploded wire attains a temperature of 20,000° and that its vapor totally absorbs light from a brilliant source; and the confirmation by Russell, St. John, and King of various predictions based on Saha's ionization theory. The last-named work has been done in the light of repeated discussions with the physicists and chemists of the California Institute of Technology, and partly in direct cooperation with Dr. Noyes. Future possibilities have been enlarged by the design of a 50-foot interferometer telescope, with independent equatorial mounting, already under construction, and by the preparation of plans for a new physical laboratory, which, if funds for its erection can be obtained, will greatly facilitate our laboratory researches.

But as we record these evidences of progress, we are saddened by a heavy loss, keenly felt throughout the scientific world. The death of Professor Kapteyn on June 18 removes from us a great and inspiring pioneer, to whom astronomy owes, as Eddington has said, its first firm footing among the intricacies of the stellar universe. Before him all attempts to make order out of seeming chaos had been in vain. Double and multiple star-systems, globular clusters, and irregular star-groups moving together in space were known. But the vast mass of stars had yielded no sign of larger relationship and the constitution of the Galaxy was a sealed mystery. Kapteyn's great discovery of the two star-streams, which comprise between them a large proportion of all stars whose motions are known, pointed the way that many astronomers have since pursued with success. His carefully devised plan for the intensive study of the stars in selected areas of the sky, toward the realization of which observatories in all parts of the world have contributed, will be continued, it may be hoped, by his friends and collaborators. We at Mount Wilson, who have profited greatly by Kapteyn's wide vision and wise counsel, and have enjoyed the advantage of his personal friendship, shall be glad to do our full share toward its completion.

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A different mode of approach to the problem of the structure of the universe, pursued at Mount Wilson with marked success, is that of Dr. Shapley, who has made use for this purpose of his photometric studies of the stars in globular clusters. His conclusion that the galactic system is vastly larger than was formerly supposed, though attacked in some quarters, has received substantial support from several recent studies. Shapley's appointment as director of the Harvard Observatory deprives us of another able investigator, but we shall hope to continue to cooperate with him in the study of stellar problems.

Turning now to the results of the year, we may first refer to the extensive investigation by Mr. Seares on the masses and densities of the stars. Our knowledge of absolute magnitudes has been greatly extended by the spectroscopic results of Adams and his associates. With these and other data, especially those for visual binaries, a progressive change of absolute magnitude with spectral type is found, ranging from −1.6 for B0 through A, F, G, and K dwarfs to +9.8 for Ma. For the same types the geometric mean masses for single stars, derived from the hypothetical absolute magnitudes of binaries, vary progressively from 10 to 0.6, respectively, in terms of the sun's mass. The small dispersion in mass among visual binaries of known parallax is noteworthy, and, as Russell has pointed out, may be a consequence of the use of the spectroscopic method in which line-intensity perhaps depends wholly upon the temperature and density in a star's atmosphere (p. 231). By an indirect method, however, Russell has confirmed the conclusion that the dispersion in mass is small.

The densities, effective temperatures, surface brightness, and volumes of both giant and dwarf stars have been derived by Seares from a discussion of this material. The later-type dwarfs are found to be considerably hotter than giants of the same type and to be about 500,000 times as dense. The surface brightness, checked by Pease's measurements of stellar diameters for a few giants, ranges from +4.8 for stars at the lowest temperature to −2.7 magnitudes at the highest (sun = 0). These results, with some exceptions, support Eddington's theory of the radiative equilibrium of giant stars and the pulsation theory of Cepheids and tend to confirm the empirical proportionality of mass to radius. Changes of temperature and pressure at various points within a star are shown by theoretical computations to be such as to maintain an approximately constant degree of ionization throughout, implying a nearly constant mean atomic mass which changes but little in giants of increasing temperature, even with marked changes of density (p. 235).

Through a combination of the values of the masses of the dwarf stars with the space-velocities obtained at Mount Wilson, Seares has found that the mean energy (mean mass × mean square space-velocity) for all types of dwarfs from A0 to Ma is practically constant, in spite of a variation in mass of 10 to 1. Assuming that equipartition of energy holds for giants such as the Cepheid variables, the probable dispersion in mass among 28 such stars for a given magnitude and type is only about 20 per cent.

The spectroscopic method of determining absolute stellar magnitudes has received further important development in the hands of Mr. Adams and Mr. Joy. Through the rigorous classification of stellar spectra and the separate grouping of stars giving diffuse lines and stars giving sharp lines, the absolute magnitudes of the white (A) stars, not measurable by the earlier method, are derived. This permits the spectra of 544 stars, previously photographed with the 60-inch and the 100-inch telescopes, to be utilized for parallax work, thus yielding a large and welcome addition to available data (p. 231).

The continuation of measurements of radial velocity has led to the accumulation of many results which have already been used by Strömberg and others in discussions of stellar motions. A list of over 1,000 stars with radial velocities obtained at Mount Wilson has been prepared for publication by Adams and Joy and should prove of especial value to astronomers because of the large proportion of stars with known distances. In addition to these results, the completion of the determination of the velocities of stars of the Md type of spectrum by Merrill provides the material for an investigation of the motions of this important class of variables (p. 229).

The stellar spectroscopic work of the year has included a great variety of investigations in addition to those already mentioned. Among these, reference may be made to the studies of the spectra of variable stars by Adams, Joy, and Merrill; Sanford's computations of the orbits of spectroscopic binaries; spectral classification of faint stars in the Selected Areas by Humason; and measurements by Sanford tending to confirm the relative displacements of enhanced and arc lines in the spectra of bright stars. The report of the Commission on the Spectral Classification of Stars, prepared for the International Astronomical Union by Adams and Russell, represents an attempt to add to the existing system of classification symbols which shall describe in a more adequate way numerous important characteristics of stellar spectra (p. 233).

Of especial significance in its bearing on our knowledge of the nature of the two star-streams discovered by Kapteyn and the character of the motions of the stars within our stellar system is an investigation by Mr. Strömberg of the space-motions of stars of spectral types A to M. With the aid of the parallaxes obtained for the A-type stars by the recently discovered spectroscopic method of Adams and Joy, and the radial velocities observed at Mount Wilson and other observatories, Strömberg has computed the individual space-velocities for 332 stars. An analysis of these motions at once leads to the important conclusion that Kapteyn's first stream may be identified with the Taurus group and his second stream with the Ursa Major group. The remaining stars belong to a central group of small systematic motion, which is the O group of Halm and with which the B-type stars probably are associated.

The results of a similar investigation of stars of types F to M show that the giant stars form a single group with a small systematic motion relative to the commonly adopted origin. Their velocity distribution is ellipsoidal and shows a regular diminution of ellipticity with spectral type, being nearly spherical for stars of the later K and M types. The dwarf stars also form a distinct group as regards their motions. Their distribution is ellipsoidal, but the directions of the axes and the systematic motion of the group differ from those of the giant stars. Rapidly moving stars, regardless of spectral type or absolute magnitude, show an extraordinary avoidance of motion in the direction of the first quadrant of longitude relative to our Galaxy.

Mr. Hubble has completed an investigation of the relationship between stars and diffuse nebulæ. Particular stars, obviously involved in luminous nebulosity, are found to have spectra similar to those of the nebulæ. If the stellar spectra are earlier than B1, the nebulæ give emission spectra; if later than B1, the spectra of the nebulæ are continuous. At the critical type B1 the nebular spectra are mixed. The relationship thus suggested is strikingly confirmed by the observed dependence of the extent and brightness of the nebulæ upon the apparent magnitude of the stars involved. The photographic magnitudes of the stars, over a range of more than 14 magnitudes, are in linear relationship with the logarithm of the greatest angular extent of associated nebulosity. The results indicate that the amount of light radiated from the nebulosity, whether it have an emission or a continuous spectrum, is equal to the amount of light received from the dominating star or stars. This indicates, as Russell had previously suggested on theoretical grounds, an absorption and re-emission of starlight by the nebulosity rather than simple reflection, and points to important possibilities of further researches (p. 222).

The great division in the Milky Way between Ophiuchus and Aquila contains within its borders a number of objects catalogued as nebulæ. Hubble has photographed many of these and finds them all to be clusters of faint stars, in some cases extremely condensed. The rather high color-index of these stars may be due to their type, or perhaps to scattering by the extensive dark nebulosity which Hubble believes to account for the forked appearance of the Milky Way.

From a theoretical investigation of the dark nebulæ, Professor Russell concludes that these objects, catalogued in great numbers by Barnard, probably consist mainly of dust particles a few millionths of an inch in diameter, driven away from stars by radiation pressure. Particles of the most effective size (with a circumference 1.12 times the wave-length) and of the density of water are repelled from the sun with a force 10 times, and from white (B) stars 100 times, greater than gravitational attraction. Dwarf stars, on the contrary, hardly repel dust at all. The final effect of the repulsion of fine dust would be to scatter it to an indefinitely great distance, were it not for the gravitational forces of vast masses of dust, which may account for the sharp outlines of dark nebulæ. In Russell's opinion, such an object as the Great Nebula in Orion consists of wisps and clouds of dust, slowly drifting about and carrying gas with them. When in the radiation field of the Trapezium stars this gas is rendered luminous; brilliantly so, with excitation of the nebular lines, in the near neighborhood of the stars; faintly, without bright lines in the outlying regions. In some places this secondary radiation is partly or completely obscured by intervening dust clouds, producing the dark structures seen visually and in photographs (p. 223).

The measurements of Mr. van Maanen upon three additional spiral nebulæ confirm results already obtained from four others and point to motion outward along the spiral arms rather than rotational motion. From these values combined with radial velocities, and from a discussion of the proper motions of a large number of spirals and the theoretical considerations of Jeans, van Maanen arrives at parallaxes for the spirals of from 0".0001 to 0".0010. This would indicate distances considerably less than would be required by the island universe theory (p. 224).

Van Maanen, assisted by Gingrich, has carried on measurements of parallax and proper motion and has now determined the trigonometric parallaxes of 160 stars. A new discussion of the systematic errors of these parallaxes by several methods, some of which depend upon objects whose distances are known with high accuracy from independent sources, yields a result of −0".0024±0".0003. Several objects of especial interest have been investigated and the probable distance of the nebula near *o* Persei is found to be about 350 light-years (p. 225).

The continuation by Mr. Pease of his measurements of stellar diameters with the 20-foot Michelson interferometer has given results for α Orionis and α Scorpii in fair agreement with those obtained previously. A slightly larger value for the angular diameter of α Orionis perhaps is to be ascribed to the effects of seeing. A study of the visibility curves of α Tauri, α Boötis, and β Pegasi indicates that the fringes of these stars would disappear at a separation of the interferometer mirrors of about 25 feet, which would correspond to an angular diameter of 0".019. A more extensive extrapolation gives probable values of 30 to 40 feet for the separation in the case of γ Andromedæ, and 40 to 50 feet in that of α Arietis (about 0".013 and 0".010, respectively). Numerous stars have been observed for which the visibility of the interference fringes is from 50 to 80 per cent (p. 236).

The use of an auxiliary interferometer with one variable aperture, as suggested by Michelson, for the purpose of calibrating the principal set of fringes, has been investigated extensively by Pease. Under good conditions of seeing this has proved most valuable for determinations both of visibility and of seeing. With poor seeing, however, the two sets of fringes show marked relative variations, and simple visual estimates based upon experience appear to be preferable (p. 237).

Immediately after the first successful measurements of the diameter of α Orionis, Messrs. Hale and Pease made provisional designs of a 50-foot interferometer, on independent equatorial mountings. These were too expensive, however, for serious consideration, and the problem was dropped for the time. As it is now evident that a large instrument of this kind must be provided, Hale has devised a 50-foot interferometer telescope, the detailed design of which has been worked out by Pease and Nichols. The essential feature of this instrument is its extreme simplicity of form, and the precautions which have been taken to avoid the necessity of large and expensive machine work. Theoretical considerations indicate that the diameter of more than 30 stars brighter than the fourth magnitude can be measured with this instrument, the construction of which has been undertaken in our instrument and optical shops (p. 241).

In the department of stellar photometry reference may be made to the progress in the determination of the photographic magnitudes of the stars in the Selected Areas under the direction of Mr. Seares. The combination of the Mount Wilson and Groningen magnitudes is now complete for 67 areas and half finished for 72 others. The study of the colors of the stars in the areas of the 30° zone is well advanced and similar observations have been made upon a few other fields of exceptional interest. In one of these, Selected Area No. 110, which lies between two branches of the Milky Way south of Cygnus, the star density is remarkably low and the stars are red, no color-index of less than 0.5 mag. having been observed among the stars between the fourteenth and nineteenth magnitudes (p. 226).

A photometric catalogue of the central stars in the planetary nebulæ is being made by Hubble. The photographic magnitudes of 20 stars and the photovisual of 10 have been determined so far, with color-indices ranging from −0.2 to −0.7 mag.

Seares and Humason have carried out a further investigation of the magnitude scales for the stars of the Polar Sequence from plates taken with the 10-inch refractor. These results, together with the investigation by Jones at Greenwich, appear to leave little doubt of the reliability of the scales now available. Seares has devoted much time to this subject in connection with the preparation of the report of the Commission on Photometry for the meeting of the International Astronomical Union at Rome. A series of standard magnitudes was adopted at this meeting which is based upon eight separate determinations of the photographic scale made at six different observatories. For stars brighter than the sixteenth magnitude the average deviation of a final magnitude for any one observatory is ±0.024 mag. (p. 227).

The measurement of the total radiation of stars is a subject of great interest and promise, as remarked in a previous report. Nicholson and Pettit, who began the development of special thermo-couples for solar investigations and for use with the Koch microphotometer, have also obtained valuable results in the measurement of stellar radiation. Coblentz made excellent observations of stellar radiation in 1914 with a thermopile attached to the 36-inch Crossley reflector, and discovered that "red stars emit two to three times as much total radiation as blue stars of the same photometric magnitude." One star of class N was found by him to give twice the deflection of a class M star of the same visual magnitude. Nicholson and Pettit find the following values of the ratio of total energy of stars of different spectral types to that of an A0 star of the same visual magnitude: A0, 1; K, 3; Ma, 9; Mc, 16; N, 16; Md, 1300 (at minimum). The extraordinarily great proportion of infra-red radiation in the case of the Md stars indicates, as Milne has pointed out, the very low temperature of 1700° C. A very important feature of Nicholson's and Pettit's work is its extreme precision, rendered possible, among other means, by a photographic recording device. Six observations of Vega at different altitudes gave values which, when plotted against air-path, indicated 0.002 magnitude as the largest residual. The application of this method to the detection of very slight variations in the radiation of bright stars will depend upon the precision with which the atmospheric absorption can be eliminated (p. 237).

Mr. Abbot has applied an improved type of vacuum bolometer and galvanometer to the measurement of the energy spectra of Aldebaran, Capella, and Betelgeuse at the coudé focus of the 100-inch reflector. The first successful bolometric determination of the distribution of energy in the spectra of stars is an event of great importance in the progress of astronomy. Using a prism of U. V. crown glass with an equivalent angle of 36°, a galvanometer with a period of single swing of 1.56 seconds and a mirror-scale distance of 4.7 meters, Abbot observed visually maximum deflections of 14 mm. in the infra-red of Betelgeuse and about one-half that amount in Aldebaran and Capella. The energy distribution in the spectrum of Capella is found to be similar to that of the sun, while that of Betelgeuse is very different and shows a sharp maximum at 0.83 μ. The spectrum of Aldebaran shows results intermediate between those for the other two stars.

The extraordinary degree of sensitiveness required for these observations is shown by the fact that with the apparatus used the current passing through the galvanometer corresponding to a deflection of 1 mm. on the scale is 2.5×10^{-11} amperes, and the corresponding rise of temperature of the bolometer strip 8×10^{-8} degrees centigrade. In Abbot's opinion an increase of at least tenfold in sensitiveness can be attained, and with the aid of photographic registration deflections of 0.5 mm. can be observed without difficulty. This will make it possible to secure spectrobolometric observations of stars to the third and possibly the fourth magnitude (p. 239).

Professor Michelson's investigations of the possibility of measuring the velocity of light between two stations separated by a distance of over 20 miles show that while the intensity of the return beam in the direct Foucault arrangement with the rotating mirror is insufficient, ample light may be secured by a combination of the Foucault and Fizeau forms of apparatus. In the form adopted the observer sees the light returned from the distant station with an intensity which depends upon the speed of the rotating mirror. The light gradually becomes less intense as the speed of the mirror increases, falls to zero, and then suddenly rises to its full amount when the speed is such that a second face of the rotating octagonal mirror replaces the first. The observation accordingly consists in adjusting the speed of the mirror to the rate at which the light suddenly reappears, and with good seeing Michelson considers that this can be done with an error not exceeding 1 part in 55,000. Apparently the measurement of the speed of the mirror with the requisite accuracy will present no serious difficulty, to judge from previous experience. The essential question of the intensity of the return light being answered satisfactorily, we expect to be able during the coming winter to construct the apparatus necessary for a complete test of the method when Michelson returns next summer (p. 242).

Reference was made last year to the experiment devised by Michelson for examining the effect of the earth's rotation on the velocity of light. If a beam of light is divided and sent around a circuit of 1 mile in opposite directions, the resulting interference fringes, according to the generalized theory of relativity on the hypothesis of a stationary ether, should show a displacement of about 0.15 fringe. If no displacement or one smaller than this amount were observed, the result would be difficult to reconcile with the theory of relativity, but would point rather to an ether completely or partially dragged along by the earth in its rotation. Experiments were made by Michelson on Mount Wilson with two circuits, 6,500 and 5,200 feet in length, and although fringes were observed, their quality was such as to preclude the possibility of accurate measurement. In these tests the path of light was close to the level of the ground, and it is possible that a site might be found for which the conditions of seeing would be greatly improved. If this could not be done, it is probable that Michelson's suggestion of a pipe line exhausted of air would offer a definite solution of the problem (p. 244).

The use of an iris diaphragm not far from the focus of a telescope has been suggested by Michelson as a means of securing objective measurements of conditions of seeing. The aperture of the diaphragm is diminished, thus diminishing the effective aperture of the telescope until diffraction rings appear. Tests made by van Maanen with such a diaphragm on the 60-inch telescope show that the simple relationship

$$S' = 1 - 0.15\,d$$

where S' is the seeing on a scale of 10 and d the effective aperture of the mirror in inches, represents the results of observation in a satisfactory way (p. 245).

The solar activity has continued to diminish, and many days now occur on which no sun-spots are visible (p. 210). Of the 33 spot groups observed during the first four months of 1922, 4 were of irregular polarity. Although this high percentage (10) of irregular spots might be due to the small number observed, a close watch of all spots has been kept as the minimum approaches. As a result a small spot was observed by Ellerman on June 24 which is probably the forerunner of the new spot cycle. Its latitude was 31° north and its polarity was opposite to that of regular preceding spots in the northern hemisphere.

Messrs. Hale, Ellerman, Nicholson, and Miss Mayberry have detected invisible sun-spots by searching for evidences of the Zeeman effect in promising regions, such as areas of flocculi following a large spot. A special polarizing apparatus permits very small magnetic fields to be found by the alternate widening to red and violet of the iron triplet λ6173. These observations confirm the view that a spot represents a vortex, which becomes visible only when the cooling due to expansion is sufficiently great to produce a perceptible decrease in the brightness of the photosphere (p. 212).

The continued study of the Zeeman effect in sun-spot spectra by Hale, Nicholson, and Ellerman has yielded further results bearing on the variation of the field-strength at different levels. Nicholson has proved that the apparent displacements of the p-component of spot triplets on photographs taken with a compound quarter-wave plate are subjective phenomena, due to the photographic influence of closely adjoining lines. The results are also important in their bearing on other classes of spectroscopic work (p. 212).

The results of the cooperative efforts of a number of observers of standards of wave-length are seen in the adoption at the Rome meeting of the International Astronomical Union of a list of 305 tertiary standard lines in the arc spectrum of iron to be used as reference lines on the international system of wave-lengths. The values adopted depend upon an average of five or six observations, and have a probable error of less than 0.001 A. The measurements of St. John and Babcock have contributed in an important degree to this valuable collection of material, and the difficult task of combining and weighting the observations has in large measure been carried on by St. John as chairman of the Commission of Standards of Wave-Length (p. 214).

In continuation of their previous work, St. John and Babcock have measured the wave-lengths of several hundred solar lines, with the double purpose of securing standards for the revision of the table of solar-spectrum wave-lengths, and studying the relative displacements of the lines in sun and arc which form so essential a test of the generalized theory of relativity. The complicated variety of phenomena in the sun which may give rise to the displacements of lines requires extensive investigation, and the study of the shift between center and limb is well adapted to throw light on some of these difficult questions. The powerful spectroscopic apparatus of the 150-foot tower telescope and an interferometer used in conjunction with the Snow telescope are being employed in the measurement of these small displacements (p. 215).

St. John, assisted by Miss Ware, has continued throughout the year his study of the solar rotation. No measurable change has been detected during the 8 years now covered by his observations, but they will be extended to include a complete sun-spot cycle. Especial attention is being given to the rate of rotation in high latitudes, where it now seems probable that Faye's formula does not fully represent the results of observation (p. 217).

Russell, King, and Noyes have obtained important results supporting the validity of Saha's theory of ionization in solar and stellar atmospheres. Barium is highly ionized in the reversing layer of the sun, and even in spots, though neutral atoms are also present. Russell has explained on theoretical grounds why it is more highly ionized than sodium, in spite of the equality of their ionizing potentials. King has confirmed in the electric furnace Saha's prediction that the enhanced lines of calcium, strontium, or barium, obtained when these elements are vaporized alone or in the presence of elements having equally high ionizing potentials, are not visible when substances like potassium or cæsium, of lower ionizing potentials, are vaporized with them. He has also found, in harmony with Saha's theory, that a mass of gas too cool to emit light is still able to absorb lines of the principal series (p. 246). King has photographed the absorption spectrum of iron at 1600° as far as λ2298, though the emission spectrum for the same temperature ends at λ3440 (p. 247). He has also found that the A and B bands of oxygen in the solar spectrum can be produced in the laboratory by the absorption of air columns only 7 and 40 meters long, respectively. The water-vapor band *a* was observed with an air-path of only 9.5 meters, under conditions of low humidity (p. 250). These results have an important bearing on the question of the presence of oxygen and water-vapor in planetary atmospheres.

The above results were obtained with the new and very effective vacuum furnace. The old furnace is being used by King, in collaboration with Noyes, in a study of the conductivity of vapors at high temperatures (p. 248). It is especially well adapted for such work because of the high temperatures available, the control which may be kept over the temperature and other conditions during the experiments, and the ease with which the concentration of the vapor may be varied. In the work so far carried on with the chlorides of calcium, sodium, and potassium, preliminary measures indicate that the variation of conductivity with the square root of the concentration appears to hold for temperatures as high as 1600° C. The use of temperatures as high as 2000° seems to be well within the range of the apparatus.

The value of Anderson's method of electrically exploded wires has been further demonstrated. A sensitive thermopile, used in conjunction with a quartz spectrograph, has permitted the spectral energy distribution of the radiation to be measured, showing that the maximum value of $E\lambda$ is at a wave-length less than λ2800 and probably below λ2400. The energy distribution corresponds almost exactly with that of a black body at a temperature of 20,000° C. Although the average pressure in the explosions is less than 5 atmospheres, the layer of vapor (about 4 cm. thick) is completely opaque to radiation. This fact may prove to be of considerable importance in solar and stellar physics (p. 248).

Babcock has made an interesting study of the green auroral line with a Fabry-Pérot interferometer. With a camera working at F/4 or faster, the fringes can be photographed in a few hours at Pasadena on any night, even when the sky is moderately cloudy. Preliminary work on Mount Wilson shows that the width of the line does not exceed 0.035 A. Improved instrumental arrangements will soon give precise measures of the wave-length and a reliable determination of the maximum width of the line (p. 240).

At the desire of Dr. Day, director of the Geophysical Laboratory of the Carnegie Institution of Washington, a cooperative plan has been undertaken for the study of the volcanic gases emitted by the crater of Kilauea at times when the level of the lava is high. Attempts will be made to photograph the spectra of the burning gases with small spectrographs especially built for the purpose in our instrument shop. These were designed by Babcock, who will join the expedition when conditions at the volcano become favorable for observational work (p. 253).

Reference was made last year to the repetition on Mount Wilson of the Michelson-Morley experiment by Professor Dayton C. Miller, of the Case School of Applied Science. Although this work has been carried on as an independent investigation, we are permitted by Professor Miller to give the results of his most recent observations. These indicate that the displacement in the direction of that due to a possible ether drift can not exceed one-tenth of the predicted amount. It is possible, however, that certain factors to be considered in computing the predicted displacement are not complete (p. 245).

Dr. H. O. Wood has continued his seismological investigations under the auspices of the Carnegie Institution of Washington. The Observatory has been able to render assistance to a certain extent in the design and construction of apparatus.

The constant search for new instruments and methods, always a prime factor in our policy, has been continued throughout the year. The chief results, most of which have been mentioned in preceding paragraphs, are the method of measuring the absolute magnitudes of the A stars; the application of the bolometer to the measurement of the distribution of energy in stellar spectra; the improvements in thermo-couples and their application to the Koch microphotometer; the use of the electric furnace for precise conductivity measurements; the new method of measuring the velocity of light; the method of detecting invisible sun-spots; the method of measuring the quality of seeing; the use of the Fabry-Pérot interferometer for work on the aurora; the use of pyrex glass to reduce the heat distortion of cœlostat mirrors; the design of the 50-foot interferometer telescope, and the design of a 75-foot spectrograph for a new physical laboratory in Pasadena. The latter instrument will differ materially from the 75-foot spectrograph of the 150-foot tower telescope, as the focal length of its collimator can be made 13, 30, 50, or 75 feet, while cameras of any desired dimensions, from a portrait lens of 10 inches aperture and 45 inches focal length to a two-lens system of 75 feet focal length, can be used with any suitable collimator.

It goes without saying that in all of this work the Division of Drafting and Design, the machine and optical shops, and the Construction Division on Mount Wilson remain indispensable. The latter has built a reservoir on Mount Wilson of 530,000 gallons capacity, to protect us against possible droughts, such as have been threatened in recent years. The shops have been operated to their full capacity, and the long list of instruments and optical surfaces produced testifies to their efficiency (p. 253).

STAFF.

The Director has continued his solar investigations, and has devoted much time to the design of a new physical laboratory and a 50-foot interferometer telescope. At the end of May he was forced by illness to go abroad for a year's rest, leaving the Observatory in the charge of Dr. Adams.

Dr. Walter S. Adams, Assistant Director, has remained in charge of the department of stellar spectroscopy. Professor Frederick H. Seares, superintendent of the Computing Division and editor of the Observatory publications, has been engaged in photometric and related investigations. Dr. Arthur S. King, superintendent of the Physical Laboratory, has made further studies of spectra in the electric furnace, with special reference to problems relating to ionization. Dr. Charles E. St. John has been engaged in wave-length determinations and in researches on the solar rotation and the spectrum of Venus. Dr. J. A. Anderson has continued his examination of the spectra of explosive discharges and has conducted further tests with Mr. Jacomini of the ruling-machine. Mr. Harold D. Babcock has made wave-length determinations with interference apparatus and has applied a small interferometer to the study of the auroral spectrum. Mr. Francis G. Pease has continued the measurement of the diameters of stars with the 20-foot interferometer in addition to his work on instrument design. Dr. Paul W. Merrill has extended his investigations on the spectra of long-period variable stars and other special types of stellar spectra. Dr. Adriaan van Maanen has measured parallaxes and proper motions and has studied the motions in spiral nebulæ. Professor Alfred H. Joy, secretary of the Observatory, has been engaged in determinations of radial velocity and of spectroscopic parallaxes. Mr. Ferdinand Ellerman has continued solar observations and has remained in charge of the general photographic work of the Observatory. Dr. Seth B. Nicholson has carried on observations on the sun and Venus, and in conjunction with Dr. Pettit has made measurements of the radiation of stars with thermopiles. Dr. Gustav Strömberg has taken part in stellar spectroscopic observations and has carried on investigations on stellar motions. Dr. R. F. Sanford has investigated the orbits of spectroscopic binaries and has continued his work on R-type stars. Dr. Edwin P. Hubble has been engaged in studies of nebulæ and nebulous stars and the nature of the radiation of nebulæ. Dr. Edison Pettit has carried on solar observations and radiation measurements on stars. Mr. Milton L. Humason has made direct photographic observations and has begun spectroscopic investigations of the stars in the Selected Areas. Mr. Wendell P. Hoge, night assistant with the 60-inch telescope, has taken part in the stellar spectroscopic work. Mr. Edison Hoge, who carried on solar observations and assisted in the photographic work, resigned on June 1. Mr. Joseph O. Hickox has been appointed to this position. Mr. Sinclair Smith has acted as part-time assistant in the Pasadena Laboratory throughout the year and has assisted Professor Michelson in his investigations.

In the Computing Division, Miss Mayberry has assisted the Director in his investigations of the sun-spot spectrum. Miss Ware and Miss Miller have been associated with the work of Dr. St. John. Miss Miller resigned on April 1 and Mr. Edward F. Adams was appointed to her position. Miss Burwell, Miss Brayton, Miss MacCreadie, Miss Poole, and Miss Shumway have been engaged in stellar spectroscopic work, and Miss Joyner and Miss Richmond in photometric investigations. Miss MacCreadie resigned on June 1. Mrs. Marsh has continued to assist Dr. van Maanen in his measurements of stellar parallaxes and the motions in spiral nebulæ. Miss Keener has given all of her time to the work of the Physical Laboratory. During the temporary absence of Miss Poole and Miss Keener their positions were filled by Miss Helen Davis and Miss Louise Ellerman. Mr. Theodore S. Jacobson, of Stanford University, assisted in the measurement and reduction of stellar spectrograms during the summer months. Miss Connor has continued in charge of the library and has assisted in the editorial work.

Dr. John C. Duncan spent the summer months at the Observatory and made direct photographs of nebulæ in addition to stellar spectroscopic observations. Dr. Bertil Lindblad, volunteer assistant from the University of Upsala, returned to Sweden in October 1921. Dr. Knut Lundmark, also of the University of Upsala, joined the staff as volunteer assistant on June 1. Dr. Lundmark is carrying on investigations on the effective wave-lengths of nuclei of spiral nebulæ and on related problems. Professor D. T. Wilson, of the Case School of Applied Science, spent the winter months in Pasadena and served as volunteer assistant during a portion of that time. Dr. C. H. Gingrich, of the Carleton College Observatory, spent the greater part of the year at the Observatory as volunteer assistant and took part in observations of proper motion and trigonometric parallax.

Professor A. A. Michelson, of the University of Chicago, Research Associate, has continued on Mount Wilson his investigations on the velocity of light and the relative motion of the earth and the ether. Professor Henry Norris Russell, of Princeton University, Research Associate, spent two months during the winter in Pasadena and carried on several studies bearing on ionization phenomena and related subjects.

INVESTIGATIONS IN PROGRESS.

SOLAR RESEARCH.

INSTRUMENTS.

The instruments used for solar investigations have remained without material change during the year. The circulating system used to control the temperature of the mirrors of the 150-foot tower telescope has been modified slightly and several attachments have been added to the spectroscopic apparatus.

SOLAR PHOTOGRAPHY.

Solar photographs were made with the 60-foot tower telescope during the year ending August 31, 1922, by Messrs. Ellerman, Nicholson, Pettit, E. R. Hoge, and Hickox. They were distributed as follows:

Photoheliograms of 6.5-inch image, 428 on 280 days.
Spectroheliograms with 5-foot spectroheliograph (Hα, entire 6.5-inch disk), 203 on 203 days.
Spectroheliograms with 13-foot spectroheliograph (K and Hα, 2-inch disk and prominences: portions of 6.5 inch disk with Hα and monochromatic light from continuous spectrum), 788 on 266 days.

The Snow telescope and the 150-foot tower telescope were used wholly for spectrographic and interference observations.

SUN-SPOT ACTIVITY.

The number of groups observed during the calendar year 1921 was 140 as against 168 in 1920 and 295 in 1919. Of these, 73 were in northern and 67 in southern latitudes. There were 31 days on which no spots were visible at the time of observation, including a period of 9 consecutive days in November. The average number of groups observed each day was as follows:

Month.	Daily number.	Month.	Daily number.
January....	2.7	July.........	3.5
February...	2.6	August......	2.0
March	2.5	September...	1.8
April.......	2.8	October	1.8
May.......	1.4	November...	1.4
June.......	3.0	December ...	1.8

The average daily number for the year was 2.3, with an average latitude of 10°, as compared with 11° in 1920 and 12° in 1919.

SUN-SPOT POLARITIES.

As in previous years, drawings of sun-spots were made daily at the 150-foot tower telescope, showing their positions, polarities, and field-strengths. The following table summarizes the results of these observations:

Hemisphere.	Polarity.		
	Regular.	Irregular.	Undetermined.
North.........	55	2	15
South.........	54	3	11
Whole sun.....	109	5	26

The reversal of polarities observed at the last sun-spot minimum has led us to keep a close watch for spots in high latitudes, which sometimes appear well in advance of the coming cycle. The first case of this kind was detected by Ellerman on June 24. A small single spot, found at N. lat. 31°, was classed magnetically as V 4. No companion was seen, and the spot did not appear again. But in view of its high latitude and the fact that its polarity was opposite to that of regular preceding spots in the northern hemisphere, it appears to be a forerunner of the coming cycle. Owing to partial cloudiness, no calcium spectroheliograms could be made, and the position of the spot with reference to the surrounding flocculi is uncertain.

A very exceptional number of irregular spots (those having polarities opposite to the regular rule) was discovered during the first four months of 1922. This led us to tabulate the irregular spots of previous years, with the results given in the following table:

Polarity of sun-spots 1908–1913 and during present cycle.

Year.	Regular.	Irregular.		Complex.	Unclassified.	Range in latitude.	Average latitude.
		Spots.	Per cent.				
1908..... 1913.....	24	2	8	....	....	18°– 3°	9°
1914.....	32	2	6	0	....	34 –13	22
1915.....	141	2	1	3	36	29 – 2	19
1916.....	286	14	4	0	38	37 – 4	17
1917.....	414	14	3	3	19	30 – 1	15
1918.....	358	16	4	1	20	30 – 0	13
1919.....	272	5	2	2	18	30 – 1	12
1920.....	152	3	2	4	9	23 – 1	11
1921.....	109	5	4	1	25	19 – 0	10
1922[1]	46	5	10	2	3	31 – 2	9

[1] The first 8 months of the year.

Five irregular spots, out of a total number of 46, were observed during the first eight months of 1922, giving the unusually high proportion of 10 per cent. In 1921, however, 4 of the 5 irregular spots recorded during the year were among the 32 spots seen in the third quarter, thus corresponding to nearly 13 per cent. In the first quarter of 1920 over 5 per cent of the 39 spots were irregular in polarity. The important feature of the irregular spot of June 24, 1922, is its very high latitude, which almost certainly marks its inclusion in the next cycle.

In the above table the proportion of irregular spots is given as a percentage of the number of spots classified, not of the total number of spots. The ranges in latitude and the average latitudes are for all the spots, but no tendency for the irregular spots to be grouped in any special latitude has been found.

A satisfactory plan of publishing the daily magnetic observations made with the 150-foot tower telescope, by which the polarities and field-strengths of all spot groups can be seen at a glance, has been worked out during the year with the assistance of Mr. John L. Ridgway, who has made admirable specimen drawings. Similar drawings covering our entire series of records will be prepared, and published after the close of the present spot-cycle.

INVISIBLE SUN-SPOTS.

The minor member (usually the following spot) of a bipolar group is often very unstable, sometimes disappearing and reappearing on successive days. After its final disappearance, both calcium and hydrogen flocculi continue to mark its place. These facts, together with the comparative infrequency of single spots and the tendency of spot groups to break out again and again at the same heliographic position, raise the question whether embryo or decaying spots, invisible to the eye, may not be detected on the sun.

If the umbra is actually present, but insufficiently dark to be seen by the eye, it might conceivably be rendered visible by some device for increasing the contrast, such as photography with ultra-violet light of very short wavelength. Preliminary experiments with this end in view have not proved successful. Or a thermo-couple, used differentially, might measure the slight difference in radiation. But a third method has the advantage of revealing the vortex which appears to be the essential element of a spot, even when there is no change whatever in the intensity of radiation at the point in question. For the vortex may produce a magnetic field, even when the cooling caused by expansion within it is too slight to affect appreciably the radiation or absorption of the whirling vapors.

In order to detect the weak magnetic field of such a vortex, a half-wave plate is mounted above the quarter-wave plate and Nicol prism regularly employed for polarity observations with the 75-foot spectrograph of the 150-foot tower telescope. This is caused to oscillate back and forth across the slit by a small electric motor, so that the half-wave plate is alternately interposed and withdrawn. If a large spot is on the slit, the red and violet components of the iron triplet λ6173 will then be cut off alternately. The position of an invisible spot is betrayed by a slight oscillation of the line to right and left, due to the alternate extinction of its red and violet edges.

Several invisible spots have been found in this way since systematic search for them was begun last autumn. Some of them have followed the disappearance of a spot, others have preceded its visible stage, and in still other cases no visible spot has appeared at the point of observation. The field-strengths measured, from 200 to 500 gausses, are of the same order as those of the smallest visible spots. It is hoped that the method may prove useful in the study of spot formation.

THE *p*-COMPONENT IN SUN-SPOT SPECTRA.

Measurements of the wave-length of the *p*-component in sun-spot spectra have shown considerable changes in position, the line in every case being shifted away from the *n*-component present on the photograph. The suggestion was made by St. John that this result might be due to the influence of the *n*-component, the two lines forming a pair similar to those for which he had obtained too wide a separation when measured in the solar spectrum. Two different experiments were made by Nicholson to test this possibility.

In the first experiment, photographs were made of a single-line of the iron arc spectrum through the same spectrograph (75-foot) that was used for the sun-spot spectra. Three exposures were made. For the first and third a toothed occulting bar was employed, so constructed that the exposed part of the slit for the third exposure corresponded to the covered part of the first. The middle exposure gave a simple image of the line which should be as straight as the slit itself. Between the exposures the plate was moved by amounts of the order of the displacements between the *p*- and *n*-components in the sun-spot spectra.

The resulting photographs show an apparent displacement of the central line similar to that found for the *p*-component; and measurements give results of the same order, though not quite so large, as those found in the spot spectrum. It is evident that in these measures the observer does not set the micrometer wire on the place of maximum absorption, but half-way between the edges of the line. Hence if the edges of two lines actually overlap, the edge of the line on the free side is estimated to lie farther from the center than the edge on the side next to another line. If this is the case in spot spectra the "peak" of the *p*-component should not be shifted.

A second test was made with the aid of the Koch microphotometer, thermocouples being used in place of the photo-electric cells. Photographs were made of the intensity curves of the line λ6173 on several strips of the spot spectrum, and the positions of the maxima of these curves were then measured. The depression between the *p*- and *n*-components is rather shallow on these photographs, and better results probably could now be obtained because of improvements in the microphotometer. The results, measured directly from the negatives and from two sets of microphotometer curves, are as follows:

	Plate T′1709.		Plate T′1713.	
	p	*n*	*p*	*n*
Measured displacements...	−0.061 mm.	+0.689 mm.	−0.074 mm.	+0.713 mm.
Microphotometer values...	−0.016	+0.643	−0.024	+0.629

The probable error of both sets of measures is about 0.01 mm. Although the sign of the displacements of the *p*-component is the same in both cases, the values are reduced so greatly in the case of microphotometric curves that the residual, if of any significance, is probably due to photographic causes. The microphotometer has been fitted with an improved thermo-couple, and will be used for additional studies of this character. Meanwhile, the spot plates have been used to give relative measures of the field-strengths at different levels, and it is hoped that the precision of these determinations can be increased by further work.

RADIOMETRIC OBSERVATIONS OF THE SUN AND SUN-SPOTS.

Mr. Pettit and Mr. Nicholson have used their sensitive thermo-couples for measurements of the distribution of energy across the sun's disk and across sun-spots. For this work a self-registering apparatus was designed, the galvanometer deflections being recorded as curves on a moving photographic plate in the same way as in the bolometric observations of Abbot and others.

Drift curves taken across the disk, showing both the total radiation and that for various wave-lengths between 0.4μ and 2.0μ are in satisfactory agreement with those already obtained with the bolometer. The study of similar curves of the total radiation across sun-spots and faculæ leads to the following conclusions:

(1) The total radiation of the center of the sun-spots which have been investigated averages 52 per cent of that of the neighboring photosphere.

(2) The decline in radiation in passing from the photosphere to the center of the spot is continuous over the penumbra, the rate of change increasing as the umbra is approached.

(3) The total radiation from the faculæ is from 7 to 10 per cent greater than that from the adjoining photosphere. This indicates that the faculæ considered as black bodies have temperatures about 130° higher than the photosphere.

Energy curves have also been made of the spectra of sun-spots and the neighboring photosphere. The ordinates of these curves are measured and from a series of photographs the mean values are derived for the ratio between the radiation from the spot and that from the photosphere for any given wave-length. These ratios are, of course, independent of losses by transmission through the earth's atmosphere. A curve constructed from these values shows the following characteristics:

(1) The radiation in sun-spots decreases from 82 per cent at 1.7 μ to 30 per cent at 0.4 μ.

(2) Broad absorption bands are indicated in the sun-spot spectrum at 1.37 μ, 1.92 μ, and to a less extent at 0.94 μ.

From measurements of the slope of this curve in the region of maximum radiation, on the assumption of Planck's law and a temperature of 6500° C. for the photosphere, the radiation temperature of spots is found to be 5530° C. The total radiation gives very nearly the same result.

THE DISPLACEMENTS OF SOLAR LINES.

In the last annual report a brief discussion was given of the state of the observational evidence regarding the existence of displacements between solar and arc lines of the size required by the generalized theory of relativity. According to this theory, the gravitational shift of the solar lines should be +0.010 A at λ5000. A complete study of the question, therefore, involves: (1) an accurate determination of terrestrial wave-lengths; (2) an accurate determination of solar wave-lengths; (3) an extensive study of the causes giving rise to displacements of lines in the sun, such as general and local convection, lateral drifts, pressure and possible effects from density distribution, and irregular refraction and dispersion. Investigations of all three of these problems are in progress by Mr. St. John and Mr. Babcock, and their results at the present time, as well as their methods of studying the complicated phenomena involved in solar displacements, may be summarized under corresponding heads.

Terrestrial Wave-Lengths.

The report of the Commission on Wave-Lengths, adopted at the Rome meeting of the International Astronomical Union in May 1922, shows the important progress which has been made in the determination of the wave-lengths of the lines in the spectrum of the iron arc. The 300 lines adopted as tertiary standards after a careful investigation of the character of the source and the elimination of those recognized as unstable, show such a degree of accordance for the different observers as to indicate a probable error of less than 0.001 A. On the average, each wave-length has been measured by five or six observers, and so complete and accurate are the results that the spectrum of this important element naturally will serve as the basis for future determinations of wave-length.

Solar Wave-Lengths.

The question whether the wave-lengths of the lines at the center of the sun are constant is a vital one in studies of the relative displacements of arc and solar lines. The Mount Wilson observations indicate that in the direct comparisons of these sources the more carefully conditions are controlled and instrumental errors are eliminated, the smaller become the deviations between separate determinations. The following table, prepared by Mr. St. John, shows the accordance of the wave-lengths of lines at the center of the sun when observed on different dates:

No. lines.	Region.	1917, Mean.	1921, April 21.	1921, April 29.	1921, May 1.	1921, June 1.
13	λλ4337–4401	0.5545	0.5552	0.5550	0.5565	0.5554
17	4489–4607	....	.5574	.5594	.5593	....
15	4615–4688	....	.3942	.3941	.3945	....
20	4707–4784	....	.5217	.5217	.5216	....

These measurements were made on grating spectrograms. The results with the interferometer are of about the same order of accuracy.

In view of the probable existence of convection currents in the solar atmosphere, this constancy of wave-length at the sun's center is rather surprising. It appears to find its explanation in the fact that at any given level these currents reach a comparatively steady state, although at different levels they may differ both in amount and direction.

Mr. Babcock has continued his measurements of the wave-length of lines at the sun's center with an interferometer attached to the Snow telescope. These observations extend toward the violet as far as λ4000, but are incomplete for wave-lengths shorter than λ5000. In the interval between λ4000 and λ6923 about 900 lines have now been measured on from 1 to 15 photographs. The wave-lengths are determined by reference to the iron arc, and in the region of wave-length longer than λ5000 may be compared with those obtained by Mr. St. John with the high-dispersion plane-grating spectrograph. For 184 lines common to both lists, the difference, interferometer *minus* grating, is zero for 33 lines, positive for 88, and negative for 63. The mean deviation is 0.002 A and the mean difference taken with regard to sign is +0.0004 A. Measures are now in progress which, with the addition of a comparatively small number of new photographs, will extend the work as far as is practicable into the ultra-violet.

The data which are being collected in this investigation, when combined with the corresponding measures made with the grating spectrograph, will provide, on the one hand, the basis for a new table of standard solar wave-lengths, and on the other the direct observational material for a discussion of the gravitational shift of the solar lines required by the theory of relativity.

Center and Limb Displacements in the Sun.

One of the phenomena, the study of which is well adapted to throw light upon the complex question of the sources of the displacements of solar lines, is that of the relative shift between the lines at the center and the limb. First discovered by Halm in 1907 and later studied more extensively by Adams, this effect requires a thorough reinvestigation with the aid of powerful modern spectroscopic apparatus, a large image of the sun, and direct comparison with terrestrial spectra. As is well known, the spectral lines at the sun's limb, when compared with those at the center, are affected in two ways: first, they are in nearly all cases shifted toward the red by slight amounts which vary from line to line; second, they are in general wider and more diffuse in character and change their appearance in a variety of ways. No adequate explanation of the cause of these effects has as yet been found.

Mr. St. John and Mr. Babcock have undertaken the investigation of this subject by several different methods, using both grating spectrographs and an interferometer. The instrumental difficulties encountered in obtaining thoroughly reliable measurements of the small displacements involved make such independent observations especially desirable, the range in the differences between different spectrograms being sometimes four or five times as great at the limb as at the center of the sun. The 150-foot tower telescope and 75-foot spectrograph, and the Snow telescope and 30-foot spectrograph have been used for the grating spectra, while the interferometer work has been carried on wholly with the Snow telescope.

With the latter instrument two series of photographs are now being secured. A new set of totally reflecting prisms has been mounted on the 30-foot spectrograph, and these make it possible to photograph strips of spectrum, two from the center of the sun, two from one limb, and one from the opposite limb. A rotating sector reduces the intensity of the light from the center, so that all exposures are simultaneous. Observations are made at varying distances from the sun's limb along both the equatorial and the polar diameters. To eliminate so far as possible instrumental errors, the spectrograph and prism system are reversed with respect to the sun's image between exposures, the prism system is reversed with respect to the spectrograph, and atmospheric lines are used to check the results. In this way 30 spectrograms, each containing 4 or 5 exposures, have been taken, covering the region λλ4900–6400.

The results of the measures, which are as yet incomplete, indicate fairly close agreement with those obtained from photographs taken with the 150-foot tower telescope and 75-foot spectrograph, primarily for the study of the solar rotation.

A second series of observations on the limb effect is being made by Mr. Babcock with the aid of an interferometer, the small diaphragm of the etalon being placed at various positions along the sun's polar radius. Differential measurements are made between the spectrum from the center and from each of these points along the radius. The atmospheric lines are used to eliminate instrumental changes which may occur during the successive exposures. While this method is not very well adapted to points very near the limb, it is extremely useful along the greater part of the sun's radius. The few measurements so far obtained are in fair agreement with those from the method in which a grating is used.

The question has been raised by Evershed whether the amount of the displacement is not different at the north and south limbs of the sun. From the extensive results obtained as a by-product of the work on solar rotation, Mr. St. John concludes that the difference, limb *minus* center, is the same, within the limits of error, at corresponding points of the two hemispheres, as well as within the same hemisphere. The table on the following page shows his results for the differences in the limb displacement, southern *minus* northern hemisphere.

Spectrograph circle reading.	λ5300, 238 observations.	λ6300, 126 observations.
15°	−0.0006 A	−0.0005 A
30	0.0000	+0.0002
45	−0.0001	−0.0002
60	−0.0004	+0.0001
75	+0.0002	+0.0001
80	+0.0002	−0.0002
85	+0.0006	0.0000

CONSTANCY OF WAVE-LENGTH OF ATMOSPHERIC LINES.

Reference has been made to the importance of the use of atmospheric lines as standards for wave-length measurements and as criteria for instrumental adjustments. Since the work of Pérot at Meudon has indicated a variation of wave-length with altitude which differs greatly on different days, it has become necessary to investigate the question as thoroughly as possible. The observations of Evershed at Kodaikanal and those at Mount Wilson are in agreement in showing that their wave-lengths are independent of altitude and constant from year to year. The results of Mr. St. John and Mr. Babcock for the fractional part of the mean wave-length of 8 lines of the a band for a period of 11 years are given below:

1911	1912	1913	1914	1915	1916	1917	1918	1919	1920	1921
0.214	0.213	0.214	0.216	0.214	0.212	0.213	0.212	0.214	0.214	0.215

SOLAR ROTATION.

The observations by Mr. St. John and Miss Ware with the 150-foot tower telescope now extend over the period of 8 years from 1914 to 1921. They give no evidence of a progressive change from year to year. The plan of work contemplates the continuation of the observations through an 11-year period, increased emphasis being given to observations at high latitudes, because the data at present indicate that the formula of Faye may require modification in these regions. To determine accurately the period of rotation at high latitudes, a greatly increased number of observations will be required, since the effects due to local disturbances are often larger than the quantities to be observed. In this investigation the spectra of center and limb are taken simultaneously and the observations are distributed symmetrically in sets of four, the spectrograph being rotated and the reflecting prisms thus placed successively at corresponding points in each quadrant. This method of observation makes it possible to study each hemisphere separately and to measure the limb-center displacement at each point of the limb.

Through the use of spectral regions where atmospheric lines occur, it becomes possible to study also the local disturbances at both center and limb. Since the amount and frequency of these disturbances may be greater the larger the image, similar and simultaneous observations will be undertaken with the Snow telescope, which gives an image but two-fifths as large as that of the 150-foot tower telescope. The use of duplicate instruments will also separate the influences of personal equation from those which depend upon the instruments. As a further check, observations for rotation will be carried on with the interferometer equipment of the Snow telescope.

WAVE-LENGTHS IN SKYLIGHT AND IN THE SPECTRUM OF VENUS.

Mr. St. John and Mr. Nicholson have continued their observations of the spectrum of Venus with a view to determining the cause of the apparent displacements of the spectral lines found by Evershed. From observations made in 1919–20 they concluded that the differences between the wave-lengths in skylight and in sunlight reflected from Venus could be represented best by an empirical formula based on the consideration that atmospheric dispersion at the low altitude at which the observations necessarily are made when the phase angles are small produces an unsymmetrical illumination of the slit of the spectrograph. This is due to the fact that the photographs are made in the violet portion of the spectrum, while the guiding is done upon the visual image.

As a test of this question, a series of 85 spectrograms was made in 1920–21, 41 with Venus east, with phase angles 43° to 92°, and 44 with Venus west, phase angles 107° to 25°. A blue ray filter was used in the guiding telescope, so that the observer was able to keep the photographic image symmetrically placed upon the slit. These spectrograms were measured and the results compared with those from 66 similar spectrograms of skylight. In the earlier series taken with the observer guiding upon the visual image, the wave-lengths from photographs obtained at low altitudes had been found to be systematically shorter than those from photographs at high altitudes. In the present series this difference is practically zero. The mean wave-length derived from 20 lines on 37 spectrograms, taken at average altitude 14°, is 0.001 A larger than that from 48 spectrograms taken at altitude 28°, a quantity within the limits of errors of measurement.

A definite test of the variation of wave-length with the angle Venus-Sun-Earth is afforded by the following comparison of observations made at nearly constant altitude, but with different values of this angle:

Angle V-S-E.	Altitude.	Venus-skylight.	No. of plates.
42°	15	−0.001 A	9
52	13	−0.002	6
74	15	−0.002	8
96	13	0.000	4
125	13	0.000	10

The results offer strong evidence against a shortening of wave-length in the sunlight reflected by Venus from the solar hemisphere turned away from the sun.

The material collected in this investigation provides the data for a determination of the solar parallax and a study of the rotation period of Venus, and will be used for these purposes when the measurements have been completed.

ABSENCE OF OXYGEN AND WATER-VAPOR LINES FROM THE SPECTRUM OF VENUS.

Reference was made last year to the results of Mr. St. John and Mr. Nicholson which point to the absence of the absorption lines of oxygen and water-vapor from the planet's atmosphere. Since that time Mr. King has found through measurements in the laboratory that a column of air 39.5 meters in length, equivalent to 8 meters of oxygen, will show the lines of the B band of oxygen with an intensity comparable to that of lines of intensity 1 on Rowland's scale. Investigations of the intensity of the lines just visible on the spectrograms of Venus indicate that the equivalent of a depth of 9.2 meters of oxygen under conditions corresponding to those in the laboratory should give visible lines. Since in these observations of Venus the path of the light is several times the radial depth of the atmosphere, ranging from 5.2 to 7.2 in some cases, it follows that the absence of absorption lines means that above the level at which reflection takes place there is less than the equivalent of 1, or at most 2, meters of oxygen capable of absorbing radiation in the same way as gas in the laboratory. The oxygen in the earth's atmosphere is equivalent to a column 1,500 meters in depth, so that the oxygen in the portions of the planet's atmosphere accessible to observation can not be more than one one-thousandth that of the terrestrial atmosphere. From similar considerations it may be shown that there is less than 1 mm. of precipitable water in the layer of the planet's atmosphere traversed by the solar beam. It is proposed to extend the observations to the band near λ7200, since the lines of this band can be produced by smaller quantities of water-vapor than those of shorter wave-length.

FOCAL CHANGES PRODUCED BY TEMPERATURE CHANGES IN CŒLOSTAT MIRRORS.

Mr. Pettit has made a number of tests of the effect of the sun's heat upon the cœlostat mirrors of the Snow telescope and the two tower telescopes in producing changes of focal length. In the case of the Snow telescope the glass mirrors were tested and then replaced by speculum mirrors. It was found that with the speculum the amount of change was only two-fifths as great as with the glass, and that a constant focus was reached in about 1 hour as against 1½ hours for the glass mirrors. A comparison was also made between the speculum mirrors in the Snow telescope and the glass mirrors of the 60-foot tower telescope. The latter showed much greater ranges of focus, which continued over a decidedly longer period of time.

An investigation of the focal changes of the 150-foot tower telescope showed that the effect of the liquid circulating system around the mirrors is to reduce the amount of change by about one-third of its value. The time required to reach a constant focus is about 7 hours as against 4½ hours without the cooling system. During this time the change appears to be nearly linear. In February a test was made after replacing the usual mirrors with two 12-inch pyrex-glass mirrors, 2 inches in thickness. The changes in focus were found to be very greatly reduced, being only about two-fifths as great for the pyrex mirrors without the cooling system as for the ordinary mirrors with the system in operation. The time required for the pyrex mirrors to reach a constant focus was found to be only 50 minutes, and no tendency to astigmatism was noted during observations extending over the succeeding 7 hours.

DISTRIBUTION OF LIGHT IN THE SOLAR CORONA.

Mr. Pettit has applied the registering microphotometer to the measurement of the distribution of light in the corona, using for this purpose photographs obtained by him at the eclipse of 1918 at Matheson, Colorado, with exposure times ranging from 1 to 40 seconds. A turntable equal in diameter to that of the sun's image was made to rotate beneath the microscope objective in synchronism with the linear travel of the registering apparatus, and, by means of a cross-slide on the microscope stage, the limb of the sun was set at different distances from the optical axis of the microscope. In this way curves were obtained which represent the distribution of light in the corona at various distances from the limb. With this apparatus streamers and details in the outer corona can be traced to points beyond that at which they can be seen on the photographs. A nearly linear relationship is found to hold for the law of darkening of the image along the fainter portions of the corona, but in the bright streamers the rate of darkening increases rapidly as the inner corona is approached. The expression of these measures in terms of luminosity and the corrections to be applied are being investigated.

RESEARCHES ON STARS AND NEBULÆ.

OBSERVING CONDITIONS.

The winter season of 1921–22 surpassed all records since the establishment of the Observatory in the amount of precipitation. For the year ending August 31 this reached a total of 60.5 inches, which is about 75 per cent above the normal. In a single storm, December 17–26, the precipitation amounted to 29.38 inches. The total snowfall for the year was 84 inches. The mean temperature was 56° F., the maximum 95° on July 5, and the minimum 15° on December 19. The average wind velocity was 10.3 miles an hour, with a maximum on December 21 of 80 miles an hour.

Owing to the exceptional amount of cloudiness and the atmospheric disturbances accompanying the frequent storms, the observing conditions for the year were somewhat below the normal, both as regards clearness of sky and seeing. The 60-inch reflector was used during the whole of 193 nights and during parts of 84 nights. These were distributed as follows:

Observing record of 60-inch reflector.

	Hours of darkness.	Hours clear.	Hours cloudy.	Observations.		
				All night.	Part of night.	None.
1921						
September....	295	255	40	23	3	4
October	336	234	102	21	4	6
November....	330	188	142	12	10	8
December.. ..	346	88	258	7	5	19
1922						
January......	346	157	189	10	10	11
February.....	308	111	197	7	7	14
March........	324	174	150	12	10	9
April.........	286	153	133	10	15	5
May.........	266	198	68	21	6	4
June.........	230	189	41	21	7	2
July..........	255	216	39	26	2	3
August.......	269	218	51	23	5	3
Total ...	3,591	2,181	1,410	193	84	88
Mean for 10 years......	....	2,291	1,370	193	90	82

The conditions of seeing (on a scale of 10) and the wind velocity are added for purposes of reference:

Seeing.		Wind.	
Scale.	No. of nights.	Velocity.	No. of nights.
1	47	High........	16
2	45	Brisk........	22
3	71	Moderate....	44
4	57	Light........	101
5	40	Calm........	130
6	13	....	....
7	5	....	....
8	1	....	....

These data have all been taken from the meteorological and observing records kept by Mr. Hoge.

RESEARCHES ON NEBULÆ.

Direct Photography.

Numerous photographs, mainly of nebulæ and nebulous areas, have been made with the 100-inch and 60-inch reflectors. Among the objects of especial interest photographed by Mr. Hubble, reference may be made to the following:

N. G. C. 5253, in which the nova Z Centauri appeared in 1895. The nebula is not a true spiral, but resembles M 82 or N. G. C. 4214.

I. C. 1295. This is a faint planetary of the ring form about 2′ in diameter. The central star is estimated as of about the 14th magnitude.

R Aquarii. In addition to the faint exterior wisps previously known, a close envelope of bright nebulosity has been found to exist around this star, which probably gives rise to the bright nebular lines recorded on spectrograms. The exposure times have ranged from 3 seconds to 3 hours.

Mr. Duncan has given especial attention to extended areas and regions where dark markings are present. Among his photographs are the following:

Barnard Nos. 92 and 93. These are dark areas outlined against a star-cloud in Sagittarius. The photograph shows much faint luminous nebulosity not recorded hitherto.

Barnard No. 152 in Cepheus. A dark marking projected against a background of stars with no certain evidence of bright nebulosity.

N. G. C. 7000, southern portion. This is the well-known North America nebula. A great amount of detail, both dark and bright, is shown in the regions bordering on the "Carribean Sea." The central and western portions of the "Sea" seem to be devoid of bright nebulosity, and the star density is less than one-tenth of that within regions of such nebulosity. In this respect the similarity to that found in I. C. 434 south of ζ Orionis is striking.

Mr. Humason has made photographs of the following large spiral nebulæ, which will be used for measurements of internal motions: N. G. C. 598, 2683, 4395, 4400, 5055, 5194, 5457, 6946, 7217, and 7331.

Several photographs of the Andromeda nebula have been made by Mr. Humason and Mr. Lundmark in continuation of the search for novæ in this object. One nova, No. 21, was discovered by Mr. Humason. A number of other objects have been photographed with the two reflectors; in particular, the moon and Jupiter, by Mr. Pease, and several of the older novæ by Mr. Lundmark.

The 10-inch photographic telescope has been used by Mr. Duncan and Mr. Hubble for the study of areas in the Milky Way, both luminous and dark. A dark marking has been found at galactic latitude +37°, the highest latitude so far recorded for such objects. A small Tessar lens attached to the larger telescope is giving excellent results in the photography of the larger galactic features. Both of these instruments have been used by Mr. Lundmark for studies in star counts and the distribution of the novæ.

VARIABLE NEBULÆ.

Mr. Hubble has continued his study of the variable nebulæ with the following results:

N. G. C. 1555. Two photographs made during the year show no conspicuous change either in the nebulosity or in the associated star T Tauri.

N. G. C. 2261, 6729. Nine photographs of 2261 and 12 of 6729 have been secured during the year. The associated stars, R Monocerotis and R Coronæ Australis, have remained fairly constant, but the nebulæ have presented constantly varying appearances. These changes in the nebulosity can be accounted for in the case of both objects by progressive movements of areas of obscuration, possibly dark clouds of nebulous material, over a permanent background of luminous nebular details. These permanent details appear to vary in brightness only with variation in brightness of the associated stars. The luminous details show no indications of actual motion.

LUMINOSITY OF NEBULÆ.

Mr. Hubble's investigations of galactic nebulæ have led to the following conclusions:

(1) All diffuse nebulæ have stars actually involved in or conspicuously associated with them.

(2) There is a direct relationship between the spectral types of stars and the spectrum of the associated nebulosity. Nebulæ with emission spectra are found to be associated with stars of type B0 or earlier, nebulæ having continuous spectra with stars of B2 or later, while nebulæ giving spectra of mixed characteristics are usually associated with stars of the critical type B1. An apparent exception to these conclusions is that stars whose spectra contain strongly enhanced lines may sometimes be associated with nebulæ having emission spectra. Such cases, however, are very rare.

(3) The luminosity of diffuse nebulæ obeys the inverse-square law with respect to the associated stars as sources.

(4) Within the range of spectrum covered by ordinary Seed 30 plates, and within the probable errors of the observations, the quantity of light emitted by a given area of diffuse nebulosity is equal to the amount which the area intercepts from the associated star or stars. This holds for all diffuse nebulæ, whether their spectra are of the emission, continuous, or mixed type.

(5) The spectra of emission nebulæ never agree with the spectra of their associated stars, although for the nebulæ with continuous spectra the available evidence indicates a fairly close agreement.

The obvious conclusion is that luminous diffuse nebulæ derive their light from involved or neighboring stars. Where there are no stars properly situated or of sufficient brightness to illuminate a nebula, the nebula is dark and makes its presence known by obscuration. The mechanism of illumination, in the case of nebulæ with emission spectra at least, is not a simple reflection.

The method employed for investigating the relationship in diffuse nebulæ between luminosity and associated stars was to plot the photographic magnitude of the stars against the logarithm of the angular extent of the nebulosity expressed in minutes of arc for a given exposure-time. The form of the resulting curve, $m+5 \log a=$ constant, indicates that the inverse-square law applies. Within the errors of observation, the constant is that which is derived by spreading the light of a star of magnitude m over a spherical shell of radius a, where Seares's value of 18.8 magnitudes per square second of arc is used as the limiting surface brightness registered in an exposure of one minute.

This method was applied to a discussion of Curtis's data on planetary nebulæ in Publications of the Lick Observatory, volume XIII. A definite relationship was found to exist between m, the magnitude of the central star, and a combination of $\log e$, the shortest relative exposure-time required to register the nebulosity, and $\log a$, the angular distance from the central star to that portion of the nebula for which e was measured. When a was reduced to a_1 corresponding to a uniform e and the inverse-square law was assumed, the relationship was found to be $m+5 \log a_1=$ constant, as in the case of the diffuse nebulæ. The constant, however, indicates that in the planetaries the photographic surface brightness averages about 4 magnitudes per square second of arc brighter than the photographic light intercepted from the central stars. This discrepancy may possibly find its explanation in the complicated discontinuous character of the nebular spectra and in the extraordinary strength of the ultra-violet continuous spectrum of the central stars. The residuals are rather large, but the indications are that they can be correlated with definite characteristics of the various nebulæ. Thus the ring nebulæ show uniformly large positive residuals, and the globular types, such as N. G. C. 6572, uniformly large negative residuals.

Preliminary investigations of the luminosity of non-galactic nebulæ have been made by plotting the growth of the nebular images with increasing exposures. For N. G. C. 221, 7619, 7623, and 7625, all of which are globular nebulæ with conspicuous nuclei, the curves are represented by the equation $2 \log a-\log E=$ constant, where a is the diameter and E the exposure-time. This indicates that the inverse-square law of luminosity applies to these nebulæ as well as to galactic nebulæ. Furthermore, the value of the constant in each of these cases is very nearly that derived on the assumption that the surface brightness at any distance from the nucleus is the luminosity of the nucleus spread over a spherical shell of that particular radius. This line of investigation will be continued in order to cover as wide a field as possible in the non-galactic nebulæ.

Dust Clouds in Space and Dark and Bright Nebulæ.

Professor Russell has made a theoretical investigation of the effect of the existence of clouds of dust in interstellar space upon the light of stars and has applied his results to problems connected with the nebulæ. His principal conclusions are as follows:

(1) Of the material which may be supposed to exist in space, by far the most effective in its power to scatter light is pure dust made up of particles of the

order of 0.1 μ in diameter. A cloud of such particles containing only 0.1 mg. of matter in a column 1 cm. square and of a length equal to the thickness of the cloud may be practically opaque, the brightness of stars seen through it being diminished as much as 8 magnitudes.

(2) If the dust particles are more than 0.1μ in diameter, the scattering will be non-selective as regards wave-length. If their diameter is less than 0.05μ the scattering will be strongly selective like that of a gas, but for equal quantities of matter may be nearly 100,000,000 times as great. Stars seen through such a cloud will appear red. Theoretically it would be possible with particles of a given intermediate size to form a cloud through which a star would appear blue, but the actual occurrence of these conditions is improbable.

(3) Such fine dust will be repelled by radiation pressure from the sun and from all stars except the fainter dwarfs of types K and M. In the case of the brightest stars, especially those of type B, the repulsive force may be as much as 1,000 times the gravitational attraction. The dust will be driven out into the regions between the stars, and, since it can not be in true equilibrium there, will ultimately escape to very great distances.

(4) It is probable that this dust forms the principal absorbing material in the "dark nebulæ" which obscure portions of the Milky Way. Such clouds probably are held together by gravitational attraction; if so, their masses must be considerable, of the order of 100 times the sun's mass for a small cloud 1 parsec in diameter. In such a mass most of the material might be in other states of aggregation, but the collisions which would occur within it would supply the fine dust required to make it opaque.

(5) Extended luminous galactic nebulæ appear to owe their brightness to illumination of dark nebulæ by stars, as Hubble's investigations have shown. In some cases the starlight appears to be reflected by opaque matter, such as fine dust; in others it seems to excite monochromatic gaseous radiations, probably by some process analogous to fluorescence. In either case it is probable that the observed luminosity is superficial and confined to the starlit surface. According to this view, as wisps of dark nebulosity drift into the illuminated region near a suitable star they appear as luminous nebulæ. The motions known to exist in the Orion nebula suggest that its appearance will be entirely changed by such drifting in less than a million years. The nebula doubtless will persist, but it will be formed of new wisps and clouds which have drifted into the field of illumination of the stars dominant in this region.

Internal Motions in Spiral Nebulæ.

Mr. van Maanen has completed measurements of three more spiral nebulæ, N. G. C. 2403, 4736, and 5055. These show results similar to those found previously for M 33, 51, 81, and 101, and point more toward a motion outward along the arms of the spirals than toward a rotational motion. If such is the case, it will not be possible at present to use these values for a derivation of the masses of the spirals.

Several methods of discussing the material available have been used by Mr. van Maanen in an attempt to gain some knowledge of the probable distances of the larger spiral nebulæ. The following probably deserve the greatest confidence:

(1) Jeans's method, based on the conditions necessary for the breaking up of the line-elements of filaments thrown off by the nucleus.

(2) A discussion of the total motions of 67 spirals from the measurements of Curtis and 82 spirals from those of Lundmark.

(3) A comparison of the internal motions in 7 spirals measured by van Maanen with the spectroscopic radial velocities.

These three methods give values ranging from 0.″0001 to 0.″0010, and appear to indicate that the spiral nebulæ are at distances considerably less than those required by the island-universe theory.

Spectra of Nebulæ and Nebulous Stars.

Mr. Hubble is continuing his spectroscopic investigations of stars associated with diffuse nebulæ. The radial velocities indicate that a very large proportion of those with spectral types earlier than B8 are spectroscopic binaries, and the orbits of several will be investigated to study the possible effects of the nebulosity on orbital motion.

Spectrograms of the nuclei or central stars of 10 planetary nebulæ have been obtained by Mr. Hubble with the Cassegrain spectrographs. These all show much the same general characteristics and belong to types Od and Oe.

Mr. Humason, using the 10-inch photographic telescope and an objective prism, has discovered a new planetary nebula, and Mr. Hubble and Mr. Lundmark, with the same instrument, have secured spectra of several diffuse nebulæ and nebulous objects.

Mr. Sanford has used the small slit spectrograph at the primary focus of the reflectors for work on a few nebulæ. With this instrument, adapted for use with two prisms, and a very short camera, an exposure of 21 hours under very unfavorable conditions upon the nucleus of N. G. C. 2681 showed a continuous spectrum which extended to the violet of the K line. The spectral type is estimated as F8 and measurements of the radial velocity give a value of +700 km.

Color Indices of Spiral Nebulæ.

Photographs have been taken by Dr. Lundmark for the purpose of studying the color of the spiral nebulæ and differences of color in different portions of the same nebula. Two methods have been employed; first, direct photography with and without color screens; second, exposures through a large objective grating attached to the 60-inch reflector. This grating, designed and first used by Professor Hertzsprung at Mount Wilson in 1912, has recently been refitted in the Pasadena shops. Dr. Lundmark's first photographs were made on objects of known color for the purpose of deriving a scale and zero-point, and his results, so far as preliminary reductions have been made, confirm those of Seares and those of Lindblad and Lundmark made at Upsala.

TRIGONOMETRIC PARALLAXES AND PROPER MOTIONS.

During the year Mr. van Maanen, assisted by Mr. Gingrich, has obtained 353 photographs with 641 exposures at the 80-foot focus of the 60-inch reflector. The presence of an exceptional amount of astigmatism in the 60-inch mirror during a period in March and April made some of these photographs unavailable for measurement. The plates necessary for the derivation of the parallaxes of 16 fields have been secured, the total number of fields completed to date being 160. The measurement of the fields for the determination of the proper motions of the comparison stars has been continued by Mr. Gingrich and Mrs. Marsh and a total of 22 have now been finished. Some of the results of the year may be indicated in a brief summary:

(1) Among the objects for which parallaxes have been derived are two short-period variables, U Ophiuchi and UU Herculis; two long-period variables, R Cancri and U Herculis; and five planetary nebulæ, N. G. C. 1501, 1514, 6058, 6572, and 7226.

(2) A faint companion, magnitude 11.8, has been found by Mr. van Maanen 12′ southeast of Lalande 32324. Its proper motion, as determined by Mr. Gingrich, is 0″.575 in position angle 156°, while that of the principal star is 0″.56 in position angle 153°. Assuming the stars to have the same parallax, the fainter star has an absolute magnitude of +11.2, and its distance from the primary is 10,000 astronomical units.

(3) The measurement and reduction of a series of plates of X Ophiuchi by Mr. Gingrich shows that the displacement in the image of this close double star is due to the variability of the northern component, and that the distance is somewhat more than 0″.152. These conclusions are in agreement with those of Mr. van Biesbroeck, of the Yerkes Observatory, from visual observations.

(4) Mr. van Maanen has made a new discussion of the systematic errors of the Mount Wilson trigonometric parallaxes, using several methods, based for the most part on objects whose parallaxes are known within a few thousandths of a second of arc from sources other than direct measurement. Among these are stars of types O, B, and N; short-period variables, long-period variables, and spiral nebulæ. From 8 different comparisons it is found that the systematic error in the trigonometric parallaxes is $-0''.0024 \pm 0''.0003$. In view of the possibility that the parallaxes of some objects with very high color-indices, such as the planetary nebulæ, may be affected with considerably larger systematic errors, a series of photographs of these objects has been begun at both the primary and the 80-foot focus of the 60-inch reflector. The measurement of the proper motions from these plates will make it possible to derive mean parallaxes from parallactic motion and the τ-component.

(5) The parallaxes and the proper motions in right ascension of 20 stars in the nebulous region surrounding the star B. D. +31° 643 near o Persei have been determined by Mr. Gingrich. The mean of the parallaxes of the five stars most completely surrounded by nebulosity is +0″.0095. If this is taken as the parallax of the nebula, its distance is about 350 light-years.

At the primary focus of the 100-inch reflector Mr. van Maanen has made 224 photographs with 408 exposures. Plates have been taken as far south as γ Sagittarii, $\delta = -36°47'$, through a yellow color-screen made by Mr. Anderson, and show good images. This screen is being used for all fields south of −4°. The parallax of one eleventh-magnitude star, Wolf 1039, with a total proper motion of 1″.44, has been determined from these plates. The result is $\pi_{\text{rel}} = +0''.056 \pm 0''.004$.

STELLAR PHOTOMETRY.

The photographs relating to investigations in stellar photometry have been taken by Messrs. Seares, Hubble, and Humason.

The observations of colors of stars in the Selected Areas of the 30° zone referred to in the last report are well advanced. All but three of the twenty-four areas have been compared with the pole for the determination of the zero-point of the color-scale, and for half of the zone series of longer exposures have been made to extend the observations to the fainter stars.

A number of additional fields of special interest have also been observed, among them Selected Area No. 110, which lies between the two branches of the Milky Way south of Cygnus. The star density in this region is exceptionally low, and the faint stars are all reddish. Preliminary measures of 120 stars between the fourteenth and nineteenth magnitudes reveal no color indices less than 0.5 mag. The maximum frequency occurs for a color-index of 0.9 mag.

MAGNITUDES OF CENTRAL STARS IN PLANETARY NEBULÆ.

Mr. Hubble is engaged in the construction of a photometric catalogue of the nuclei or central stars of planetary nebulæ. Magnitudes are determined by the method of polar comparisons, the exposure-times being sufficiently short to give images of the central stars essentially free from nebulosity. The photographic magnitudes of 20 such stars and the photovisual magnitudes of 10 have already been determined. The color indices range from −0.2 to −0.7 mag.

A photometric study of the Algol variable C. C. −37° 13034 is being made by Mr. Hubble. This star is involved in the dense diffuse nebula N. G. C. 6727. The case is unique, and an accurate determination of the light-curve may provide evidence as to the effect of a nebulous medium on orbital motion and surface brightness.

Miss Mayberry has finished the measurement and reduction of the photographs of M 5 taken at the request of Professor Turner for the determination of the variation of comparison star k of Bailey's variable No. 33. The star seems to be a cluster-type variable of small amplitude. The discussion of the data for the determination of the period is in the hands of Professor Turner.

The compilation of photographic magnitudes in the Selected Areas by Miss Joyner and Miss Richmond, under direction of Mr. Seares, has continued. The combination of the Mount Wilson magnitudes with those derived at Groningen by Professors Kapteyn and van Rhijn is complete for Areas 1 to 67, and half finished for Areas 68 to 139. The Groningen results for all the areas are now in our hands.

NORTH POLAR STANDARDS OF MAGNITUDE.

An independent determination of the photographic and photovisual scales of magnitudes for Polar Sequence stars to the fifteenth and thirteenth magnitudes, respectively, confirms closely the results published by Mr. Seares in 1915. The photographs were taken with the 10-inch refractor by Mr. Humason, who has also made the measures. The discussion of these data may be found in Contribution No. 234.

A similar confirmation of the earlier results is afforded by the recent investigation at Greenwich by Jones, and by the revision of the results obtained at the Harvard Observatory. There is little doubt, therefore, of the reliability of the scales now available. Mr. Seares has discussed all of the Mount Wilson data bearing on this question, including a direct determination of the colors of the stars by the method of exposure ratios, as a preliminary to the preparation of the report of the International Commission on Stellar

Photometry. This discussion and its results have been published in Contribution No. 235.

Mr. Seares has given much time to the preparation of the report of the Commission on Photometry for the meeting of the International Astronomical Union at Rome. Eight separate determinations of the photographic scale, made at six different observatories, were combined to form a series of standard magnitudes which has been adopted by the Union. The Harvard results for stars fainter than the sixteenth magnitude were omitted at the request of Miss Leavitt. The Mount Wilson data, which extend to the twentieth photographic magnitude, are accordingly the only ones available for very faint stars, and until this portion of the scale receives independent confirmation it must be regarded as provisional. For stars brighter than the sixteenth magnitude, however, the agreement of the different investigations is very satisfactory. The average deviation of a final magnitude for any one observatory, between the limits 2.6 and 16.0, is ±0.024 mag.

The Mount Wilson measures of photovisual brightness are the only ones extending to the faint stars (17.4 photovisual). The scale stands in the proper relation to the photographic scale, however, for the color-indices obtained by comparing magnitudes show no appreciable systematic deviation from those obtained by the method of exposure ratios.

STELLAR SPECTROSCOPY.

Nearly one-half the time of the two large reflectors has been devoted to stellar spectroscopy, and numerous observers have shared in the work of this department. Among the principal lines of work carried on during the year are the following:

General program of radial velocities, determinations of absolute magnitude, and investigations of the spectra of certain classes of variable stars: Adams, Joy, Strömberg, Hoge.
Variables of type Me and Se and other stars with bright lines: Merrill, Humason.
Spectroscopic binaries and R-type stars: Sanford.
Nebulous stars: Hubble.
Stars of Kapteyn's Selected Areas: Humason.

Most of the spectrograms have been obtained with two slit-spectrographs at the Cassegrain focus of the reflectors. These have remained without change during the year, except for the recent addition to the spectrograph of the 100-inch telescope of a camera lens by T. Cooke and Sons of 6.3 cm. aperture and 12.8 cm. focal length. In the case of extremely faint objects this wide-angle lens should prove of considerable value.

The small spectrograph employed at the primary focus of the telescopes has been adapted by Mr. Sanford for use with two prisms and a lens with very short focus and excellent results have been obtained. Another spectrograph, for use without a slit, by means of which the spectra of a number of stars may be obtained at one time for classification purposes, was completed during the winter. With this instrument Mr. Humason, working at the primary focus of the 60-inch reflector, has succeeded in classifying spectra of stars in Kapteyn's Selected Areas down to the twelfth magnitude on the photographic scale.

Two other spectrographs, both for use at the Cassegrain focus of the 100-inch reflector, have recently been added to our equipment. One of these contains a concave grating used in conjunction with either a collimating mirror or lens to render the light falling upon the grating parallel. The radius of the grating is 1 meter. Mr. Merrill has employed this instrument to photograph the spectra of a number of stars in the region to the red of Hα.

The second spectrograph is designed for use on very faint stars and nebulæ and is attached to the plate-holder frame of the large reflector. Guiding is by means of an auxiliary star in the field. The large ratio of the focal length of collimator to camera, 8 to 1, should make this instrument efficient in operation.

The number of spectrograms obtained during the year with the Cassegrain spectrographs was 1,443, of which 585 were made with the 100-inch telescope and 858 with the 60-inch. The larger instrument was used mainly for stars of large proper motion and for variable stars, while the general program of observations on stars of the sixth and seventh magnitudes was carried on with the 60-inch reflector. The spectra of a considerable number of comparatively bright stars of type A were observed with this instrument to provide the material for an investigation of spectroscopic methods of deriving the absolute magnitudes of such stars.

The spectrograms were distributed as follows, according to the apparent magnitudes of the stars observed:

	100-inch.	60-inch.
Brighter than 5.0 visually ..	21	137
5.0 to 5.9..................	13	180
6.0 to 6.9..................	55	273
7.0 to 7.9..................	107	235
8.0 to 8.9..................	248	29
9.0 or fainter..............	141	4

Radial Velocities.

A large number of stars has been added to our lists during the year, many of which are being observed for absolute magnitude and not for radial velocity. For this reason, and because of the numerous variable stars upon our program, the proportion of stars whose radial velocities have been determined is somewhat less than usual.

The more important results in this line of work may be summarized as follows:

(1) The radial velocities of 140 stars have been determined from three or more spectrograms. With the completion of these observations a total of over 1,000 stars with constant velocities is now available and the results are being prepared for publication. This number does not include the results for the Md stars by Mr. Merrill, nor those for the stars of the Selected Areas by Mr. Humason.

(2) Fifteen stars with variable radial velocities have been discovered, among them several faint stars of the Cepheid and Algol types of light variation.

(3) The orbits of 4 spectroscopic binaries have been derived by Mr. Sanford, and 18 others are under observation, some of which are nearly completed. About 130 spectrograms of spectroscopic binaries have been obtained during

the year. Mr. Sanford has now determined the orbits of 11 binaries, 6 of which are dwarf stars of spectral types F9 to K2 with periods between 4 and 32 days. With the exception of Boss 2447 with a value of 0.21, all of these orbits show an eccentricity of less than 0.10.

(4) A number of spectrograms of Capella, obtained by Mr. Sanford with a dispersion of three prisms and a 102-cm. camera, were measured by him to test the accuracy of the period derived by Reese at the Lick Observatory more than 20 years ago. The values obtained show that there can be no error in the period as great as 0.01 day, and, hence, that it is unnecessary, in reducing the interferometer measures of this star, to introduce a correction for period.

(5) The radial velocities of a few additional stars of the R type of spectrum have been determined by Mr. Sanford, thus bringing the number of such stars with measured velocities to a total of 30. The spectrograms have in all cases been measured at least twice, once by means of the Hartmann spectrocomparator and a standard star of type R, and once by the method of wave-lengths. The results are in good agreement. A few spectrograms have been taken in the red portion of the spectrum of these stars near Hα.

(6) Mr. Merrill has continued his observations on the long-period variables of type Md. The radial velocities of a total of 112 such stars have been determined by him during the past 3 years. Combined with the values obtained at other observatories, velocities for 130 stars are now available. This material is being used in a study of the individual and possible group-motions of these variables, as well as in a discussion of the relative displacements of the dark and bright lines.

SPECTROSCOPIC DETERMINATIONS OF LUMINOSITY AND PARALLAX.

Since the publication of the results for 1,646 stars, the application of the spectroscopic method of deriving parallaxes has been continued as a regular part of the work of the department. The parallaxes of about 500 additional stars with spectral types F to M are now available, most of which have been obtained during the past year. These include numerous stars of very large proper motion, visual binaries some of which have dynamical parallaxes derived by Jackson and Furner or by Russell, stars in Boss's Catalogue not observed hitherto, and the stars in the Selected Areas under observation by Mr. Humason for radial velocity. No material changes have been made in the methods of reduction used previously.

Mr. Strömberg has made use of the fact that the systematic and the accidental errors of the parallaxes derived by the spectroscopic method are proportional to the size of the parallaxes themselves to determine by means of a comparison with trigonometric parallaxes the systematic corrections to the spectroscopic parallaxes, as well as the absolute corrections to some of the more extensive series of trigonometric parallaxes. The results of his investigation indicate that the system of spectroscopic parallaxes used in the catalogue of 1,646 stars is correct within the limits of error of the quantities involved. The systematic corrections to the series of trigonometric parallaxes determined at the Allegheny, McCormick, Mount Wilson, and Yerkes observatories have been found to agree satisfactorily with those derived by van Maanen and Miss Wolfe.

Professor Russell has made a brief investigation of the relationship of the masses of stars to the spectral characteristics associated with absolute magnitude. If, as seems probable, the absolute magnitude derived by the spectroscopic method depends only on the temperature and density of the stars, it may be shown that the masses of binary stars computed from spectroscopic parallaxes will be the same for the same values of the absolute magnitude. Spectroscopic parallaxes, therefore, though they will give good values for the mean masses of groups of stars, are of little value in the detection of individual differences from the mean.

A list of about 1,500 dynamical parallaxes prepared by Professor Russell at Princeton has been furnished to the Observatory in advance of publication. These results are of especial value in comparisons of spectroscopic with dynamical parallaxes and for the selection of binary systems for spectroscopic observation.

An extension of the spectroscopic method of obtaining absolute magnitudes has been made to the stars of the A type of spectrum. Investigations of the A-type stars belonging to the Taurus and the Ursa Major streams showed that when these stars had been classified as closely as possible according to spectral type and the sharp or diffuse character of their lines, a definite relationship could be established between absolute magnitude and spectral subdivision. The stars with sharp lines were found to be systematically brighter than those with diffuse lines. A similar relationship proved to hold for all A-type stars with absolute magnitudes determined from trigonometric parallaxes as well as from group motion for which spectrograms were available. In short, it was found that, within the limits of error of the determinations, there was no dispersion in the absolute magnitudes of stars of the same spectral subdivision showing lines of the same character.

The relationships derived in this way were applied to the determination of the individual parallaxes of 82 stars belonging to recognized stellar groups, and to 104 stars with parallaxes determined trigonometrically. The following comparison shows the agreement between the parallaxes obtained spectroscopically and those from group-motion or trigonometric measures:

Stars with parallaxes derived from group-motion:
  Systematic difference, −0″.0014. Average deviation, ±0″.0077.
Stars with trigonometric parallaxes:
  Systematic difference, 0″.0000. Average deviation, ±0″.0131.

These values compare favorably with those found in the case of stars of types F to M, where the average deviation between the parallaxes derived trigonometrically and spectroscopically is about ±0″.015.

This method has been applied to the determination of the parallaxes of 544 stars with spectral types ranging from B7 to F2 and the results have been published recently. An excellent degree of correlation has been found to exist between the average values of the parallaxes and the proper motions for these stars, a result which furnishes a valuable check upon the validity of the method.

It seems probable that quite similar relationships will prove to exist between absolute magnitude and spectral type in the case of stars of the B type of spectrum. It is well known that the stars of this type which belong to the earlier subdivisions, such as B0 and B1, are intrinsically brighter than those of later type, such as B8 and B9. If it should be found to be possible to employ for these stars methods similar to those used for stars of type A, the applicability of spectroscopic methods to the determination of absolute magnitudes and parallaxes would be assured for all stars with spectral types between B and M, or about 99 per cent of all those with known spectra.

Reference was made in the last annual report to the investigation by Mr. Lindblad of the influence of absolute magnitude on the more refrangible portion of the spectrum of stars of types B and A. This work was completed during the autumn, and the methods developed should prove of especial value in the case of very faint stars which can not be photographed with slit spectrographs of considerable dispersion. It is of interest to note that the spectroscopic method for deriving absolute magnitudes of A-type stars as outlined above is in full agreement with the results of Mr. Lindblad in indicating that the intrinsically fainter stars are characterized by lines which are relatively diffuse, and that this characteristic serves as an important criterion for the determination of their magnitudes.

Distribution of the Space-Velocities of Stars and Stream Motion.

An extensive investigation by Mr. Strömberg of the distribution of the space-velocities of stars of spectral types F to M was completed recently. The material used consisted of about 1,300 stars of known proper motion, parallax, and radial velocity. Spectroscopic parallaxes were used in most cases. The three components of velocity were computed from these data and the distribution of these velocities for different groups of stars relative to the galactic system was studied in various ways. With the aid of a very general form of frequency-function, of the Fourier's series type, in which the coefficients were determined directly from the number of velocity-vectors within different limits, it became possible to construct curves of equal frequency for these vectors in the plane of the galaxy and the planes at right angles to it. In this way a graphical representation of the distribution of space-velocities was obtained.

One of the principal purposes of the investigation was to decide which of the two modern theories of stellar motions, the two-drift theory of Kapteyn or the ellipsoidal theory of Schwarzschild, best represents the observed distribution of velocities. The following are some of the main conclusions bearing on this question.

(1) The giant stars of spectral types F to M form a single group with an ellipsoidal velocity distribution, the elongation of the ellipsoid being greatest for the F stars and decreasing with the later types. The distribution is nearly spherical for stars of the late K and M types.

(2) Among the fainter F-type stars there is another group, the motion of which coincides closely with that of the Taurus group. This includes about 20 per cent of the fainter stars of this type of spectrum.

(3) The dwarf stars form a distinctive group as regards their motions. The distribution of velocities is ellipsoidal, but the directions of the axes of the ellipsoid, as well as the position of its center, differ from those of the giant stars.

(4) There is a marked asymmetry in the distribution of the velocities, the stars of high velocity, regardless of spectral type or absolute magnitude, showing an avoidance of motion towards the quadrant of the sky between galactic longitudes 0° and 90°.

(5) The values of the solar motion derived from giant and from dwarf stars differ radically. The former give a value of 18.8 km. and the latter 31.7 km. The value of the solar motion is much larger if based upon stars of large peculiar motion than upon those of small motion.

A similar investigation of the space-motions of the A-type stars has been begun by Strömberg. The parallaxes used are those derived by the spectroscopic method recently developed by Adams and Joy, and the radial velocities are from the results obtained at several different observatories. The components of space-velocity for 332 stars have been computed.

The results of this investigation, so far as completed, are of especial interest in proving that the first and second star-streams, which were found by Kapteyn to be especially well marked among the A-type stars, are identical with the Taurus and the Ursa Major groups, respectively. In addition to these, there is a central group of small systematic motion which is probably identical with the antapex stream of Boss and Eddington and the O stream of Halm. This central group contains a comparatively small number of A-type stars, but probably nearly all the later-type giants, if we may judge from the agreement of their systematic motions. Over one-half of all the A stars can be regarded as members of the Ursa Major group. The stars recognized as belonging to the Taurus group are found among the intrinsically fainter A stars, a result similar to that which had previously been found to hold for those of the F type.

All of the groups appear to show an ellipsoidal distribution of velocities along nearly parallel axes, and the amount of ellipticity is of the same order as that of the F stars.

Stellar Classification.

The report of the Commission on Stellar Classification of the International Astronomical Union, prepared by Messrs. Adams and Russell, was presented by the latter at the meeting of the Union in Rome and was adopted without substantial alteration. The report embodies numerous extensions and additions to the Harvard system of classification now in general use, which have been made with a view to increasing the capacity of the system to describe spectral phenomena. No radical change, however, is suggested in the existing nomenclature.

Classification of the Spectra of Faint Stars in Kapteyn's Selected Areas.

The classification of the spectra of stars between the tenth and twelfth photographic magnitudes in the Selected Areas has been commenced by Mr. Humason with the 60-inch telescope. For this purpose he is using the large slitless focal-plane spectrograph especially designed for the work and already described. Satisfactory spectra have been obtained with this instrument on a linear scale of approximately 6.3 mm. between Hβ and Hδ. The usable field on each plate covers a region about 40′ by 40′ square.

At least 10 stars between the eleventh and twelfth photographic magnitudes will be photographed in each area. For most of the areas a single plate will give this number, but in some cases two or three plates will be needed. With an exposure time of 5 hours, well-exposed spectra of twelfth-magnitude stars are obtained at the center of the field. H and K are seen and estimates of type can be made within less than one-half of a spectral interval. In the case of the weaker spectra, of stars at the outer limits of the field, and of stars fainter than twelfth magnitude, H and K are not always visible. Some difficulty is, then, experienced in distinguishing between the early B and the late F types, as the hydrogen lines have about the same intensity, and the principal criterion is then the relative intensity of the continuous spectrum. In such cases it may prove necessary to secure more strongly exposed spectra.

MISCELLANEOUS INVESTIGATIONS.

(1) Observations of o Ceti were continued throughout the minimum of light in December. The results obtained confirm the peculiarities noted at previous minima.

(2) Observations of the spectrum of Nova Aquilæ, 1918, show that the band λ4686 has increased somewhat in strength, while only the "knobs" of the bright nebular bands N_1 and N_2 remain. Hydrogen has nearly disappeared. The ring surrounding the nucleus has diminished in brightness until it is no longer visible.

A spectrogram of Nova Cygni taken in October 1921 indicates that the spectrum had reached the nebular stage, with strong bright bands of hydrogen, nebulium, and λ4686. The continuous spectrum was very weak.

The spectrum of T Coronæ shows a marked decrease in the strength of the bright hydrogen bands and λ4686.

(3) The wave-lengths of the bright lines in the stars Boss 5650, W Cephei, and H. D. 42474, all of which show slight variations in light, have been measured. Many of the lines correspond to those in η Carinæ, but their origin in most cases is still uncertain.

(4) Spectrograms of SS Cygni and SS Aurigæ, taken at maximum of light, show that their spectra are nearly continuous with faint, wide, dark bands of hydrogen and helium. At minimum SS Cygni shows strong bright bands 20 A wide replacing the absorption bands, with possibly a trace of sharper metallic lines.

(5) Irregular variables. The spectrum of X Persei has been found to be of type B with bright hydrogen lines and sharp H and K lines. R Coronæ has a marked c-type spectrum similar to that of the Cepheid variables and has been classified as cF8. No certain variation in velocity has been detected.

(6) Variables of the RV Tauri class. Three stars of this type of variability have been observed, U Monocerotis, R Sagittæ, and V Vulpeculæ. All three show considerable range in velocity and have the spectral characteristics of high luminosity. They have been classified as cG0p, cG0, and cG5p, respectively. U Monocerotis, and to a less degree V Vulpeculæ, have exceptionally weak hydrogen lines, a condition almost certainly due to the partial balancing of absorption and emission in these lines.

(7) Studies of the Algol variable SX Cassiopeiæ have been continued. The velocity curve shows remarkable variations in amplitude and eccentricity, for which no explanation as yet seems sufficient.

(8) It has been found that the bright lines of hydrogen in the Algol variable TT Ophiuchi increase in strength as the light increases from minimum to maximum.

(9) V Sagittæ and RS Canum Venaticorum have been observed during the total eclipse of the brighter star. The spectra of the fainter stars were thus

found to be G0 and K0, respectively, the former being a giant and the latter probably a dwarf. The brighter stars are of types B8 and F3. A preliminary orbit has been computed for RS Canum Venaticorum.

(10) Examination of high-dispersion spectrograms has brought out the fact that the intensity of the zinc triplet λλ4680, 4722, and 4810 is relatively greatest in Sirius and falls off in Procyon and Arcturus. This behavior conforms to the ionization theory of Saha, and was predicted by Russell from his study of sun-spot spectra.

(11) Measurements by Mr. Sanford of stellar spectrograms taken with a dispersion of three prisms and a 102-cm. camera indicate that on photographs of this scale the differences found by Adams between the velocities given by arc and enhanced lines may be observed without difficulty.

(12) Mr. Merrill has begun a general physical investigation of red stars, with especial reference to those of the new spectral type S. These stars appear to form a third branch of the spectral sequence cognate with the K–M and R–N branches.

(13) From a study based on (*a*) spectral lines and bands, (*b*) relative strength of various portions of the continuous spectrum, (*c*) heat indices as observed by Nicholson and Pettit, Mr. Merrill concludes that the effective temperature of the reversing layer is lower in variables of type M than in those of other spectral types.

(14) Mr. Humason has discovered 7 new B-type stars with bright hydrogen lines during the year. A total of 74 such stars has now been found at Mount Wilson. In the course of this work in the spectral region near Hα, 2 F-type and 2 M-type stars with bright hydrogen lines have been discovered.

(15) Numerous measures have been made by Mr. Merrill and Mr. Humason of the complicated spectrum of B. D.+11° 4623, a star which showed recently a remarkable outburst of helium emission. A second star, H. D. 161114, has been found to show a similar spectrum.

MASSES AND DENSITIES OF STARS.

Mr. Seares has finished his investigation of the masses of stars referred to in the last report. By combining the mean masses of the dwarf stars with the mean values of their space-velocities, as derived by Messrs. Adams, Strömberg and Joy, he has found that for types F0 and later the kinetic energy of translation of these stars is nearly constant, notwithstanding the occurrence of stream motion among them. With the aid of Professor Campbell's radial velocities, the comparison was extended to the B and A stars. The kinetic energy of the B's seems to be less than that for the other types, but from A0 through to Ma, the deviations from the mean energy constant are accidental and of the order of the inherent uncertainty of the data.

The extent to which this result holds for the giant stars is open to question. In spite of this uncertainty, an attempt to derive values of the masses of the giants was made by combining their space-velocities with the mean energy constant. These results, together with the masses of the dwarf stars, gave a series of distribution curves showing approximately the relation of mean mass to absolute magnitude and spectral type for all classes of stars.

To obtain corresponding values of the mean density, the question of surface brightness was re-examined, attention being given to the differences between giants and dwarfs of the same spectral type. The adopted values of the surface brightness were checked by comparing Mr. Pease's measures of the angular diameters of 6 stars with their theoretical diameters based upon the data in question. The agreement is excellent and shows that the adopted values of the surface brightness for types later than G0 are probably near the truth. The resulting curves of constant mean density as a function of spectral type and absolute magnitude are nearly rectilinear and almost parallel to the line of maximum frequency for the dwarfs in the diagram of Russell.

The uncertainty involved in the assumption that the masses of the giant stars can be obtained from an application of the principle of equipartition, made an independent test of the results highly desirable. The Cepheid variables were used for this purpose. Almost any type of pulsation theory of variation requires that the period should vary inversely as the square root of the mean density of the star. On the assumption of this type of variation, it is thus possible to calculate *relative* values of the masses and densities of the Cepheids from their periods and spectral types alone. A comparison of results thus found with the distribution of mass and density obtained from the principle of equipartition showed a variation of the right order of magnitude. The distribution curves were modified somewhat in order to represent closely the theoretical change of mass and density for the Cepheid variables, and, as thus revised, are adopted provisionally.

A further indication that the results are of the right order of magnitude is found in the agreement of the densities with those derived from eclipsing binaries and in the coincidence of the equal-mass line $M=2$ with the line of maximum frequency of the late-type giants in Russell's diagram. The significance of this coincidence lies in the fact that Eddington has found on theoretical grounds that the value of the mass occurring most frequently among the giants should be approximately twice the mass of the sun. The details of the investigation, together with a discussion of its relation to Eddington's theory of stellar constitution, have been published in Contribution No. 226.

INTERFEROMETER MEASUREMENTS OF STELLAR DIAMETERS.

The observations made by Mr. Pease with the 20-foot interferometer beam mounted upon the 100-inch telescope have been carried on with two objects in view: first, the determination of maximum visibility for the brighter stars at a separation of the mirrors of 19 feet; second, a study of the influence of conditions of seeing upon the visibility curves. For this purpose early-type stars of small hypothetical angular diameter have been used, and the distance between the mirrors has been varied throughout a wide range.

The following are the principal results of the direct observations for angular diameter:

(1) The measures of α Orionis and α Scorpii remain essentially the same as those obtained previously. In the case of α Orionis a slightly smaller distance between the mirrors (indicating a larger angular diameter) is perhaps to be ascribed to poorer average conditions of seeing.

(2) The visibility curves of α Tauri, α Boötis, and β Pegasi are very similar and indicate a disappearance of the fringes at a separation of the mirrors of about 22 feet. The correction for seeing, at present somewhat uncertain, will probably increase this value to 25 feet.

(3) Estimates from the visibility curves point to the disappearance of the fringes at between 30 and 40 feet in the case of γ Andromedæ, and between 40 and 50 feet in that of α Arietis.

(4) The following stars have all shown high visibilities of the order of 50 per cent or more. No correction has been made for the factor of seeing.

α Canis Majoris.
α Canis Minoris.
α Geminorum.
α Ophiuchi.
α Andromedæ.
α Pegasi.
β Leonis.
γ Orionis.
γ Cassiopeiæ.
ε Cygni.

(5) The stars α Aquilæ, α Leonis, and α Virginis show practically full visibility under good conditions of seeing. For a time it was thought that the readings on α Lyræ fell below those on α Aquilæ, but full visibility has since been observed on several occasions.

The use of an auxiliary interferometer with one variable aperture for the purpose of matching the visibilities of two sets of fringes and for measurement of the seeing through disappearance of the comparison fringes has proved to be successful when the seeing is good. The principal set of fringes can be matched readily with the auxiliary fringes, and the readings showing the vanishing-point of the latter remain nearly constant during the night. Under conditions of bad seeing, however, the auxiliary and the main set of fringes have been found to vary independently of one another, the change sometimes amounting to as much as 50 per cent in a very short interval. On such nights direct eye estimates of visibility as determined through experience are used, and the seeing is judged from the character of the images themselves.

An examination of the diffraction images of a star given by the beams of light from the mirrors of the interferometer set from 8 to 20 feet apart, and a comparison with the images formed when they are less than 4 feet apart, yields some information on the question of seeing with the use of large apertures. The central disks are about 20 per cent larger in the case of the greater distance and in appearance they are somewhat more diffuse. On a night of uniform seeing the movement of the image from its central position, however, is very nearly the same for the range of from 8 to 20 feet in the separation of the mirrors.

RADIOMETRIC OBSERVATIONS OF STARS.

Measures of stellar radiation with thermo-couples were begun by Mr. Pettit and Mr. Nicholson at the 60-inch telescope in October 1921, and at the 100-inch telescope in December. On 14 observing nights, 236 complete observations were made on the total radiation from 64 stars ranging from −1.6 to 9.8 visual magnitude. In the preliminary work the galvanometer deflections were read visually from a scale, but since March 1 the deflections have all been registered photographically on a moving plate. The thermo-couple cell is mounted in the Newtonian plate-holder of the 100-inch telescope, the observations being made by shifting the star from one junction to another with one of the guiding-screws. Suitable contrivances have been provided for placing a water-cell 1 cm. thick in the path of light from the star, and for projecting an image of an electric light upon the thermo-couple for testing purposes. A cable 135 feet long connects the thermo-couple at the Newtonian focus with the D'Arsonval galvanometer in the basement, and also provides telephonic communication between the observer at the telescope and the observer at the galvanometer. When an insulating layer of cotton is placed around the thermo-couple cell the galvanometer is found to be remarkably steady. With the registering device at a distance of 6.7 meters, a deflection of 0.14 mm. has been determined from 6 deflections, with a probable error of ±0.010 mm., and similarly a deflection of 102.75 mm. with a probable error of ±0.015 mm. It is therefore essential that the plates be carefully measured on an adequate measuring-machine.

It was thought at first that seeing conditions would not affect the results to any marked extent, and in a measure this is true. The effect of poor seeing, however, is to make the flat portions of the curves irregular instead of straight lines, and this increases greatly the probable errors, especially for stars which give large deflections.

For the sake of simplicity the term "heat index" is introduced to denote the difference between the visual and the radiometric magnitudes, the two being assumed to coincide for spectral type A0. From the heat index, therefore, which is proportional to the ratio between the visual and the total radiation expressed in magnitudes, we have a means of determining the relative temperatures of stars, and hence a method for their spectral classification. Similarly, the term "water-cell absorption" is used to denote the ratio expressed in magnitudes between the radiation transmitted by the water-cell and the total radiation, and so indicates the distribution of energy in the infra-red beyond 1.13 μ. The 1-cm. water-cell used for this work has been found to transmit 90 per cent of the radiation incident upon it in the visual region, but to cut off rather sharply at 1.13 μ. No radiation is transmitted beyond 1.34 μ. The transmission curves of a considerable number of liquids are now being investigated, with a view to finding one more suitable than water for this purpose. The following table gives provisional values of the heat index and water-cell absorption, uncorrected for atmospheric absorption, for stars of various spectral classes, including Md variables:

Spectral type.	Heat index.	Water-cell absorption.
B0	−0.1 mag.	+0.2 mag.
A0	0.0	0.3
F0	+0.3	0.3
G0	0.7	0.5
K0	1.2	0.8
Ma	2.3	1.2
Mc	3.0	1.2
Md10 min. light	7.8	2.1
Md10 max. light	4.3	1.5
N	+3.1	+1.3

Some S- and R-type stars have been observed, but the deflections are exceedingly small, showing that they have little infra-red radiation compared with stars of class Md. The remarkably large deflections given by stars of type Md were first observed in ο Ceti on December 6, 1921. The star was then near minimum visual brightness, mag. 8.9, and gave a deflection about equal to that obtained from α Virginis, a star of visual magnitude 1.2 but spectral type B2. The heat index was then 7.7 mag. and the water-cell absorption 1.28 mag. It was observed shortly after maximum on June 27, 1922, when the visual magnitude was 4.5 and the deflection greater than that of Vega. The heat index was then 4.6 mag., and the water-cell absorption 1.46 mag. Between these two dates the visual brightness had changed 4.4 mag., while the variation in total radiation was only 1.3 mag. Similar results were obtained from observations of R Aquilæ at minimum and maximum. Ten stars of class Md have been studied, but all except *o* Ceti and R Aquilæ near minimum of light. Some giants and dwarfs of type K1 have been observed, but little if any difference in heat index has been noted. The M-type dwarfs have not as yet been investigated.

In addition to the variable stars of long period which are being observed at different phases of light, Algol and the Cepheid variables δ Cephei and η Aquilæ are also under observation.

The transmission of the atmosphere, which plays an important part in comparisons of the total radiation of the stars, has been studied for stars of different spectral classes. Observations on Vega, Arcturus, and α Herculis between air-mass 3 and the meridian show that the corrections follow the secant law, and that the constants are distributed according to spectral class, being smaller for α Herculis and greater for Vega.

BOLOMETRIC OBSERVATIONS OF STELLAR SPECTRA.

As early as 1916 the Director suggested to Dr. Abbot, of the Smithsonian Institution, the possibility of utilizing the great light-gathering power of the 100-inch reflector for bolometric observations of stellar spectra similar to those which for many years past he had been making of the solar spectrum. The project seemed feasible to Dr. Abbot, in view of improvements which he had in mind for increasing greatly the sensitiveness both of the bolometer and the galvanometer. Accordingly, he undertook the preparation of the spectro-bolometric apparatus which, after a long delay occasioned by the war, was completed in the spring of 1922. The actual construction of the coils and needle system of the galvanometer and of the sensitive parts of the galvanometer was carried out by Dr. Abbot's colleague, Mr. L. B. Aldrich, who has shared in all of the observational work.

The galvanometer is in vacuum and is surrounded by a special magnetic shield of 16 concentric cylinders of iron prepared by Dr. Elihu Thomson. This shield has been found to be remarkably efficient in use. The control of the needle was at first effected by the introduction of small wire magnets between the first and second shields, but later the inner shield was removed and 5 large bar magnets were used above and below the apparatus. These were found to be just sufficient to exercise the necessary control. The needle system consists of a single group of 8 thin tungsten-steel wires, each 0.9 mm. long, fastened to a glass stem 13 mm. long, which carries a platinized mirror of the thinnest microscope cover-glass 0.6 mm. square. The beam of light used to illuminate the scale descends the axis of the galvanometer, is reflected upon the small mirror by a prism, and returns vertically to a photographic recorder at a distance of about 6 meters. A number of especially brilliant experimental lamps prepared at the Nela Research Laboratory make it possible to use this long scale-distance.

The bolometer is of the special vacuum type described in Volume IV of the Annals of the Astrophysical Observatory of the Smithsonian Institution.

The spectroscope is of the Littrow type, with a 5-inch concave mirror of 45 cm. focal length to collimate the light and focus the spectrum. The prism is of Jena U. V. crown glass with an angle of 18°. It is silvered on the rear face and so is equivalent to a prism of 36°.

In the first experiments made in July the spectrometer and bolometer were used at the primary focus of the 100-inch reflector, and the galvanometer and photographic recorder were placed in the clock-room. The disturbances due to electric circuits and air currents proved, however, to be too serious to overcome. Accordingly the apparatus was transferred to the constant-temperature room south of the great pier and the telescope was used in the coudé form, the light being brought down through the polar axis. The equivalent focal length of the telescope in this form is 250 feet. In order to bring the apparatus to the center of the room, use is made of an 8-inch concave mirror of 1-meter focus placed 6 meters beyond the focus of the telescope. This forms, at a distance of 120 cm., on the slit of the spectrometer, an image, the characteristics of which are very similar to those observed previously at the Newtonian focus. Guiding and focusing are accomplished by adjustments of the 8-inch mirror; but little guiding is necessary, because of the satisfactory driving of the 100-inch telescope.

After numerous difficulties had been overcome, connected mainly with disturbances of the galvanometer, a trial was made of the apparatus on the night of August 18. Successful visual observations were obtained of the intensities of the spectra of Aldebaran, Capella, and Betelgeuse, and, on the following day, of the sun. The distribution of intensities in the normal spectrum of Capella, after correction for the effect of the earth's atmosphere, proves to be nearly identical with that of the sun, a result to be expected from a star of its spectral type. The spectral intensities in Betelgeuse are very different, showing a sharp maximum at 0.83 μ in the infra-red, and departing very widely from those in a black body with a corresponding maximum ordinate. The spectrum of Aldebaran shows results intermediate between those for the other two stars.

Although in these observations the period of the single swing of the galvanometer mirror was only 1.56 seconds, and the scale-distance employed but 4.7 meters, deflections of 14 mm. were observed in the case of Betelgeuse and over one-half that amount for Aldebaran and Capella. At this degree of sensitiveness, the current in the galvanometer corresponding to a deflection of 1 mm. on the scale is 2.5×10^{-11} amperes, and the corresponding rise of temperature of the bolometer, 8×10^{-8} degrees centigrade. Deflections of 0.5 mm. could trustworthily be observed. It appears certain that an increase of at least ten-fold in useful sensitiveness can be employed, together with photographic registration. This will make it possible to obtain satisfactory spectrobolometric observations of stars to the third and perhaps fourth magnitudes.

THE GREEN AURORAL LINE.

Lord Rayleigh, Campbell, Slipher, and others have shown that the green line characteristic of the spectrum of the polar light may be found very frequently in the spectrum of the night sky, even when no aurora is visible.

Hitherto, however, only visual observations or low-dispersion prismatic spectrograms have been made of it. In view of the uncertainty as to the origin and nature of this line and its apparent connection with solar activity, it appeared to Mr. Babcock to be a promising object for study with an interferometer, provided experiment should show that it was sufficiently intense at the latitude of this observatory.

A Fabry-Pérot etalon having plates 1 mm. apart was mounted in front of a hand magnifier of 50 mm. focal length and 25 mm. aperture. Thin films of gold cathodically deposited upon the interferometer plates gave sufficient reflecting power for green light and at the same time transmitted a large portion of it. No dispersing system was used, since no monochromatic radiation other than the green line has been found in the absence of a visible aurora. The first plate was exposed in Pasadena on the night of February 25, 1922, for 10 hours and showed a clearly defined ring system. Since that time many photographs have been made both in Pasadena and on Mount Wilson which show the ring system nearly always strong enough for measurement. The constants of the instrument, known with precision, definitely identify the ring system as due to a line in the yellow-green portion of the spectrum and leave no question as to its auroral origin. It is found possible to photograph it on nearly every clear night, and even within a few days of the time of full moon, provided a color-screen is employed. Interferometers giving orders of interference of 3,600, 8,600, 18,000, 38,000, and 85,000 for the auroral line have been used up to the present, for the most part with lenses of 75 mm. focal length. A Dallmeyer kinematograph lens working at F/1.9 is ordinarily employed, although some of the etalons are not large enough to utilize its full aperture. At the highest order of interference the bright rings are still not wider than one-half of the spectral range of the interferometer, and the resulting upper limit to the width of the line is about 0.035 A.

The preliminary values obtained for the wave-length average 0.15 A smaller than the mean of the best determinations made with prismatic dispersion. The experience so far gained indicates the possibility of measuring this wave-length with an accuracy of 1 part in 1,000,000 or 2,000,000, unless some evidence of variability is found as the work proceeds.

As might be expected, large variations occur in the intensity of the auroral light from night to night, the range being perhaps three or four fold. Some correspondence has been noted between its brightness and the state of solar activity. If this is borne out, the return of the period of maximum sun-spot activity should make it easy to secure a large amount of valuable data upon the aurora, even in the latitude of Mount Wilson.

FIFTY-FOOT INTERFEROMETER TELESCOPE.

The mechanical and optical problems presented by a 50-foot interferometer are not difficult of solution, but in order to keep the expense within moderate limits, a simple design, involving but little large-scale machine work is essential. The instrument devised by Hale, the details of which have been worked out by Pease and Nichols, embodies the optical features used by Michelson for the 20-foot interferometer in a mounting of apparently the simplest possible type.

The plane mirrors are carried on a light skeleton girder of structural steel, to be riveted together on Mount Wilson. This girder is 54 feet long and 10 feet deep in the center, tapering towards the ends. Its cross-section at the center is 4½ feet, tapering to a width of 2½ feet at a point 18 feet from the center, and maintaining this width to the extremity of the girder. On the upper surface of the girder, which is approximately straight, the rails which carry the sliding mirrors, carefully planed in sections 12 feet in length (the limit of our planer-bed), are supported by leveling screws, which permit them to be accurately alined. The outer 45° plane mirrors, 15 inches in diameter, are mounted on carriages moved simultaneously toward or away from the center of the girder by long screws driven from a single motor. Their separation may thus range from 7 to 50 feet. To permit stars of any declination to be reached, the 45° mirrors can be rotated simultaneously, by synchronous motors, about the axis joining their centers. The inner 45° plane mirrors, also 15 inches in diameter, fixed in position 26 inches apart on opposite sides of the center of the girder, are provided with fine adjustments, and one of them can be moved slightly for compensation of path. The light received from the outer mirrors is reflected to a paraboloidal mirror of 36 inches aperture and about 15 feet focal length, mounted within the girder, at its base. Since the axis of the mirror is normal to that of the girder, the rays are reflected back between the fixed 45° mirrors to a diagonal plane mirror, which sends them to an eyepiece (directly toward the pole) conveniently placed for the observer, who sits on a platform attached to the girder on the north.

The girder is carried by a strong polar axis, consisting of a short steel forging mounted on standard roller bearings, supported on a massive pier of concrete. The center of the axis passes through the center of gravity of the girder, which thus remains in balance in all positions. The end-thrust is carried partly by the bearings of the polar axis and partly by two auxiliary rollers moving on curved rails on the north face of the pier, opposite the 36-inch mirror. A worm-gear sector of 10 feet radius, bolted to the girder, is driven by a worm connected with a driving-clock at the base of the pier on the north. The range of motion is 1½ hours on each side of the meridian.

Optically the instrument is similar to the 20-foot interferometer, except that a 36-inch mirror replaces the central zone of the 100-inch, while provision is made for motion in declination by the simple expedient of rotating the outer 45° mirrors. Comparison fringes will also be arranged for, and the wedge for compensating differences in path will be like that of the 20-foot interferometer. The new instrument will be covered by a house with double walls of steel, about 60 feet long, 18 feet wide, and 20 feet high. The lower walls, to a height of 8 feet, will be fixed in position, but the upper section of the house may be rolled back, leaving the interferometer fully exposed for observations from declination −30° to the pole.

With this instrument, which is now under construction, it should be possible to check the results obtained with the 20-foot interferometer by simultaneous observations, and to measure the diameters of more than 30 stars brighter than the fourth magnitude.

THE VELOCITY OF LIGHT.

The stations used by Professor Michelson during the past summer for his investigations of the velocity of light were situated on Mount Wilson and on the ridge of Mount San Antonio, at a distance of about 23 miles. The Mount Wilson station was moved to a point just south of the power-house, where ample electric current for the arc lamp used as the source of light was available, and where the supply of compressed air for driving the rotating mirror could be maintained conveniently.

The first trials were made with the apparatus arranged essentially as described in the last report. For the distant mirror, however, a 22-inch concave of 30 feet focal length was substituted, and mounted at its focus was a small concave mirror of 30-feet radius, placed perpendicular to the axis of the large mirror. The image of the source at Mount Wilson was thus focussed accurately on the surface of the small mirror, thence returned to the 22-inch concave, and so back to Mount Wilson as a parallel beam. The adjustment of these mirrors remained surprisingly constant, and after the second trial no further expeditions to the distant station were found necessary. On the last trial of the apparatus the return light was found to disappear at a distance of less than 1 foot from the edge of the concave mirror at the home station.

When the rotating mirror was set in motion it was found at once that the intensity of the return-beam was far too small for measurement. Accordingly, Michelson had recourse to a totally different arrangement of apparatus, which is essentially a combination of the Foucault and the Fizeau forms. The light, after passing through a slit, is thrown by a lens upon the lower half of a face of the octagonal rotating mirror. From this it is reflected and an image of the slit is formed on the surface of a concave mirror of short focal length (in practice a series of 10 small mirrors placed in tandem was used). It is then reflected back to the upper half of the same face of the rotating mirror, thence to the large 22-inch concave of 30-feet focal length, and so, as a very nearly parallel beam, to the distant station. From this the light retraces its path accurately to the source. A plane-parallel plate of glass is placed in the return beam near the slit and observations are made with a low-power eyepiece.

Under these conditions, when the octagonal mirror rotates slowly, the intensity of the return beam, apart from losses by reflection and transmission, will be proportional to the angle subtended by the battery of short-focus concave mirrors. As the speed of the rotating mirror is increased, the effective arc will become less until it is exceeded by the angle through which the mirror turns during the time required for the light to pass to the distant mirror and return, when the intensity will fall to zero. As soon, however, as the speed of the mirror becomes so great that a second face replaces the first, the intensity suddenly returns to its full value. The observer, accordingly, varies the speed of the mirror,

$$n=\frac{V}{8\times 2D}=\frac{186{,}000}{8\times 46}=506 \text{ turns a second,}$$

within narrow limits until the light suddenly reappears.

With good seeing this reappearance should be very definite. The variation in mirror speed, due to poor seeing, diffraction, etc., may be estimated at

$$0.01 \text{ mm.}: \tfrac{1}{4}\,\pi r, \text{ or } 1:55{,}000$$

where r, the focal length of the small concave mirrors, is 700 mm. This will be the probable error of the result if the speed of the rotating mirror can be measured with a corresponding order of accuracy. In some previous work the error of this measurement was estimated at 1 part in 200,000, but the speed was much less than that required for these observations.

In the first trials difficulty was experienced from the light reflected diffusely from the battery of small concave mirrors, but after these had been dismounted, their surfaces retouched and covered with a "sputter" coat of platinum, much of the trouble disappeared. For future work, however, the 10 mirrors will be replaced by 2, the number of reflecting edges being thus reduced in proportion. The last test of this arrangement was made on August 25, when the return image, with the mirror rotating, was found to be so bright that it could be observed readily when the intensity was diminished tenfold.

The present system of an air-blast acting upon paddle-wheels has not proved sufficiently powerful with the air compressor now in use to give a speed of 500 revolutions a second, and some modification will be introduced before the work is continued next summer. The use of an electric motor, or possibly some form of air turbine, should readily solve this difficulty. Experiments will also be made with a view to obtaining a more steady arc lamp as a source of light.

With the definite knowledge that the intensity of the light returning from the distant station will be amply sufficient for purposes of measurement, it seems altogether probable that the method described will yield excellent results. Michelson has, however, devised a means by which the original Foucault arrangement can still be employed. A large number of small plane mirrors are adjusted on the circumference of a circle of which the axis of the rotating mirror is the center. The light from the image of the source falls on the lower half of a face of the rotating mirror and is reflected to one of the plane mirrors. Thence it is returned to the upper half of the rotating mirror, from which it is reflected to the concave, and so to the distant station. A succession of nearly parallel beams is formed as each of the small plane mirrors comes into play. When the light from the distant station retraces its path an image is formed which coincides with the source when the mirror is either at rest or rotating so rapidly that an adjacent face replaces the original one. As in the other form of apparatus, the return beam is observed with the aid of a plane-parallel plate of glass.

EFFECT OF THE EARTH'S ROTATION ON THE VELOCITY OF LIGHT.

A brief description was given in last year's report of the experiment devised by Professor Michelson for distinguishing between results which would follow, on the one hand, from the generalized theory of relativity or the hypothesis of a stationary ether, and on the other, from that of an ether either completely or partially dragged along by the earth in its rotation. The computed value of the displacement of the interference fringes as required by the theory of relativity should be about 0.15 fringe for a light circuit 1 mile in length. From the results obtained during the summer of 1921, it was hoped that the fringes would be sufficiently distinct to admit of accurate measurement.

Observations were made during the past summer over two circuits, one approximately rectangular and 6,500 feet in length, the other triangular and about 5,200 feet long. In both cases the fringes were found to be too unsteady for measurement, although the observations were made in the early evening, at the most favorable time for good conditions of seeing. Occasional improvement was seen, but this was insufficient for the purpose in view.

The path of the light in these experiments is not far above the ground, and it is possible that in the winter, with the ground covered with snow, conditions would be more favorable. Accordingly, the apparatus will be kept in readiness for observations at that season. It is also possible that a site might be selected in which the average path would be much farther from the ground-level. In the event that these two possibilities fail, recourse may be had to Michelson's original plan of a pipe-line exhausted of air to about 0.01 atmosphere.

A SCALE OF ASTRONOMICAL SEEING.

The importance of an objective scale for conditions of seeing has become especially great in connection with such refined observations as those of stellar diameters by interference methods. At the suggestion of Professor Michelson, an iris diaphragm was placed not far from the focus of the 60-inch reflector when used in the Cassegrain form. A series of observations was made by Mr. van Maanen under different conditions of seeing, the aperture of the diaphragm being varied, thus varying the effective aperture of the telescope, until diffraction rings appeared.

A comparison of the results obtained in this way, with the usual visual estimates of seeing based on a scale of 10, shows that for practical purposes the simple relationship may be used,

$$S' = 1 + 0.15\,d$$

where S' is the seeing on a scale of 10 and d is the effective diameter of the mirror. Perhaps a more rational formula, and one which has the merit of passing the zero and giving a finite value for an infinite diameter d, is

$$S'' = 10\ (1 - e^{-0.03d})$$

The following table shows the calculated values S' and S'' based on these two formulæ, compared with the visual estimates of seeing:

d	S	S'	S''
27 in.	5.4	5.0	5.5
21.6	4.5	4.2	4.8
13.5	3.3	3.0	3.3
8.1	2.5	2.2	2.1
2.7	1.5	1.4	0.8

THE MICHELSON AND MORLEY EXPERIMENT.

During the months of November and December, Professor Dayton C. Miller, of the Case School of Applied Science, repeated on Mount Wilson his observations of ether drift, using the same interferometer with a light-path of 32.24 meters, which he had employed for his previous investigations in March and April. In the hope of eliminating magnetic effects and reducing those due to radiant heat, the steel frame of the interferometer was replaced by concrete, and aluminum and brass supports were constructed for the optical parts. Observations were made at various times during both day and night and 42 complete sets were secured.

The results showed that although the displacements of the fringes previously observed for each complete rotation of the interferometer were still present, they were reduced to about one-third of the amount measured during April. The half-period displacements, which would correspond to the ether drift if present, were also observed, but were reduced to about two-fifths of their previous value, or 0.08 fringe on the average. While it seems impossible at present to draw definitive conclusions from these results, it appears to be established that the displacements observed on Mount Wilson can not exceed one-tenth of the amount predicted for the ether drift. It should be remembered, however, that the factors taken into account in computing the predicted amount are not complete.

The interferometer and steel frame have now been returned to Cleveland and Professor Miller will continue his observations with a view to detecting possible differences from the Mount Wilson results. It is also hoped to discover the source of the full-period displacement and to learn whether the half-period effect may be observed independently of the other.

PHYSICAL LABORATORY.

ELECTRIC-FURNACE INVESTIGATIONS.

Tests of Ionization Phenomena.

Certain features of Saha's theory of ionization processes admit of tests by the electric furnace, which have been carried out by Mr. King. The phenomena in question are based on the emission of enhanced lines by atoms which have each lost one electron, these free electrons forming a gas which under given conditions of temperature and pressure has a definite concentration. A further supply of electrons through the addition of a more easily ionized element should then retard the formation of ionized atoms of the first element, with a resultant weakening of its enhanced lines, while the arc lines radiated by the normal atom remain unchanged. Observations for the detection of this effect were made on the spectra of calcium, strontium, barium, and scandium. In each case the spectrum of the element alone was compared with that obtained when a more easily ionized element such as potassium or cæsium was added, and in each case the effect was found to be a weakening of the enhanced lines. Mixture with a substance having about the same ionization potential produced no effect.

In addition to the confirmation of Saha's theory afforded in this way, the results in the case of scandium, whose series relationships are now known, demonstrated that its enhanced lines arise from the ionized atom. Further, they confirmed the selection of enhanced lines obtained by other methods, and showed the approximate magnitude of the ionization potential of scandium. The scandium enhanced lines are decidedly weakened in the spectrum from a mixture with potassium and barium, having ionization potentials of 4.3 and 5.1 volts, respectively, but are unaffected by calcium, which requires 6.1 volts. This indicates an ionization potential for scandium close to that of calcium. The method can be used with other elements whose enhanced lines are within the range of the furnace excitation.

Another feature of Saha's theory is that lines of a given type should appear in absorption at a lower temperature than in emission. While more extensive observations on this point are needed, tests which have been made for the strong low-temperature lines of calcium, strontium, and barium have yielded positive results, a temperature being found in each case which gave the lines in absorption but not in emission. The effect is less decided for lines of the type of those in the iron spectrum.

Production of Absorption Spectra.

In the general work with the electric furnace, three methods for the production of absorption spectra have been developed: (1) a diaphragm may be placed in the furnace tube, and the spectrum of the vapor reversed by the incandescent background; (2) light from a high-power tungsten lamp may be passed through the furnace vapor heated to various temperatures; (3) wire explosions, according to the method of Anderson, may be used as the continuous source. By the first method, temperatures of the diaphragm above 3200° C. are obtainable, the column of absorbing vapor being heated in proportion. The second method admits of independent heating of the source and the absorbing vapor, and when a quartz window is employed has proved very effective in the region of short wave-length. The tungsten filament heated to 2900° C. builds up a continuous spectrum extending well into the ultra-violet, while the absorbing vapor may be left at a much lower temperature and permits the selection of low-temperature lines in this region. The use of wire explosions, when the material of the wire does not introduce disturbing lines, supplements the second method, and on low-dispersion spectrograms has given the shortest wave-lengths yet obtained for the furnace absorption spectra.

The study of the absorption spectrum of iron in the ultra-violet by the three methods illustrates the useful features of each. By the first method, absorption lines of iron have been obtained as far as λ2447, but necessarily only for high temperatures of the absorbing vapor. The second method reaches about the same limit, but the furnace lines which are absorbed at lower temperatures may be studied. With the third method, the absorption of iron vapor at a temperature as low as 1600° C. can be followed to λ2298.

The possibility of observing absorption lines in the ultra-violet for low furnace temperatures is a distinct addition to our means of studying such lines; for the emission spectrum of the furnace extends only as far as the continuous spectrum of a black body at the same temperature, which is only to about λ3500 for the low-temperature stage usually employed. If the continuous spectrum is produced by a very hot external source, lines absorbed by a vapor in the low-temperature furnace can be observed at least 1200 A beyond the point at which the furnace at that temperature can emit them. Since many important series lines occur in this region, the ability to classify them on the same basis as those of the visible spectrum is of much assistance.

Ultra-Violet Spectrum of Iron.

A list has been published which contains 892 iron lines between λ2298 and λ3878, classified according to their intensities in the arc and at three different furnace temperatures. The methods of producing absorption spectra, described in the preceding section, have furnished many additional data for this region, especially as regards the selection of low-temperature lines, and have allowed some extension of the ultra-violet limit of the investigation. An additional list of 262 lines between λ3884 and λ4531 supplements the results for this region published in 1913, and gives the classification of some lines previously omitted, as well as some others which have been revised in accordance with recent experimental results.

CONDUCTIVITY OF VAPORS AT HIGH TEMPERATURES.

The older electric furnace has been used for a series of experiments on the conductivity of vapors of compounds. The chemical features of the problem were planned by Professor A. A. Noyes, and the investigation has been carried out by Mr. King, with the assistance of Messrs. Weymouth, Badger, and Smith. The possibility of the use of high temperatures with the furnace, and of close control of temperature and other conditions, makes possible an extension of work which has been done at lower temperatures with flame vapors. The salt to be tested is vaporized in an extension of the furnace-tube, and is then mixed with nitrogen which flows at a known rate, thus carrying the vapor into the highly heated portion where the resistance is measured between the wall of the tube and an exploring rod supported axially. The concentration of the vapor may be changed by known amounts during the experiment. The relative conductivity under different conditions is thus measured directly, and absolute values may be obtained by checking with a liquid electrolyte used in the tubes when cold. The work thus far with the chlorides of calcium, sodium, and potassium has involved many variations of the experimental arrangements in the course of the development of an accurate method, and the series of final measurements has only just begun. The variation of conductivity with the square root of the concentration appears to hold for temperatures as high as 1600° C. A satisfactory degree of consistency for the readings has been obtained, and the use of temperatures as high as 2000° seems to be quite within the range of the apparatus.

MISCELLANEOUS.

In addition to a large number of spectrograms of iron, made with the electric furnace under various conditions to check and amplify the previous material, more or less extensive examinations have been made of the spectra of titanium, rubidium, calcium, barium, copper, and zinc, largely in connection with the ionization phenomena and the behavior of enhanced lines. Banded spectra, especially of calcium and copper, have also received attention. Photographs of the cyanogen bands with the furnace have been supplied to Dr. R. T. Birge and have been used by him in a discussion of Heurlinger's theory of band structure and as a means of estimating temperature by the location of the maximum in a band series.

ELECTRICALLY EXPLODED WIRES.

The work on electrically exploded wires has been continued by Mr. Anderson, assisted by Mr. Sinclair Smith, along four different lines.

SPECTRA.

Spectrograms have been made using wires of copper, silver, gold, magnesium, zinc, cadmium, aluminum, tin, lead, and tungsten, in addition to those of iron and nickel usually employed. In the earlier work it was observed that the spectrum of copper was much weaker than that of iron or nickel. The reason for this became apparent when it was found that wires of pure copper, silver, or gold do not explode properly when confined in a slot in a block of wood. The current passes through the wire until it is melted and vaporized, then it suddenly passes between the electrodes outside the wooden block, even if these are separated by a distance much greater than the length of the wire. The result is a very feeble effect in the slot and a brilliant spark discharge outside the block of wood; and as only light from the slot passes through the slit of the spectroscope, the resulting spectrogram shows little or nothing. If the wires are slightly amalgamated or alloyed with some other metal, they explode in the normal way, and then the spectra of copper, silver, or gold are of about the same intensity as those of other metals. This suggests that the vapors of copper, silver, or gold in the pure state are very poor conductors of electricity. All of the other metals tried behave normally. The absorption lines are in general those which show regularly in the arc spectrum of the element. Because of great intensity in the ultra-violet and the relatively small number of absorption lines, the explosions of aluminum, zinc, and lead are especially well adapted to serve as sources for the study of absorption in this part of the spectrum.

Spectral Energy Distribution.

With the aid of a vacuum thermopile, made by Messrs. Nicholson and Pettit, and a galvanometer, in conjunction with a quartz spectrograph, some of the preliminary work was done on the mapping of the energy spectrum of the explosions of iron wires. Easily measurable deflections were obtained from about $\lambda=2\ \mu$ in the infra-red to $\lambda=1990$ A in the ultra-violet. The object of these experiments was to see if energy measures are possible with this type of source, and to secure data which will be needed for the design of apparatus suitable for accurate work of this kind. They show that a quantitative study of the radiation of metallic vapors at very high temperatures is not only possible, but does not seem to offer any very great difficulties.

Opacity of Vapors at High Temperatures.

This quantity, which plays an important part in theoretical investigations in astrophysics, may be investigated directly with the explosions. By passing the light from one explosion (A) through a second one (B) connected in series with it, it is possible to measure how much of the light of any particular wavelength from A passes through B. It is found that if B is an explosion in a slot, giving a continuous spectrum, while A is a spark or an explosion in the open giving a discontinuous spectrum, B is quite opaque, no light from A being transmitted through it; while, if the light from B passes through A, a considerable fraction is transmitted, showing that A is only partially opaque. The method, when properly developed, promises to give quantitative data concerning the absorption coefficient, especially when used in conjunction with the method described in the next paragraph.

Velocity of Sound in High-Temperature Vapors.

A method has been developed which makes it possible to determine the velocity of sound in metallic vapors at very high temperatures. This method is as follows: An image of the open-air explosion seen end on, for example, is projected upon the slit of a rotating-mirror camera. The photograph made in this way shows the explosion drawn out into a band of light of great intensity at the beginning, but gradually fading out as the vapors cool by radiation. The image of the slit moves over the photographic plate at the rate of about 40,000 cm. per second, and as the records obtained for different elements vary from 8 to 20 cm. in length for open-air explosions, it follows that the vapors are luminous during $\frac{1}{5000}$ to $\frac{1}{2000}$ of a second. The first 3 or

4 cm. of the record represent the first stage, when energy is passing into the vapor from the oscillations of the condenser, while the remainder of the record shows the second stage, when the vapor is cooling by radiation, no energy being given to it from the circuit. It is in this second stage that the velocity of sound is determined. If a sound-wave passes through the vapor in a direction parallel to the slit, it will be registered on the photograph, since the adiabatic compression in the sound-wave elevates the temperature momentarily, causing a momentary increase of radiation. The result is a bright line inclined at an angle to the axis of the band of light, which is found to be easily measurable. Since the linear speed of the slit-image with respect to the photographic plate, the lateral magnification, and the value of this angle are all known, it is a simple matter to calculate the velocity of sound in the vapor. The source of sound is the explosion itself, a cylindrical or spherical reflector placed a few centimeters from the wire returning the wave to the explosion. By varying the distance between the reflector and the wire, the sound-wave may be made to strike the cylindrical mass of vapor at any desired time after the beginning of the explosion.

Since the velocity of the sound-wave gives T/m (T=absolute temperature of the vapor, m its molecular weight), it is clear that this quantity may be determined at any instant of time during the cooling of the vapor. And since m is now pretty accurately known, as a result of Saha's theory, the temperature may be calculated, and hence the rate of cooling by radiation. Moreover, by comparing the intensity of the light at any point with the intensity of a black body of known temperature photographed with the same apparatus, the rate of emission of energy may be determined. Finally, by comparing the rate of fall of temperature with the rate of emission of energy, it should be possible to deduce the apparent specific heats of the vapors.

New Apparatus.

The rotating-mirror camera is being modified so that it will be better suited for accurate work. A two-stage mercury diffusion pump of the latest type has been installed in order to make possible a study of the explosions and other phenomena in very high vacua. Glass plates for a new high-voltage condenser have been ordered, and this additional unit should be available during the coming year.

COMBINED EFFECT OF ELECTRIC AND MAGNETIC FIELDS ON RADIATION.

The experiments mentioned in the last report on the combined Zeeman and Stark effects have been continued by Mr. Sinclair Smith, and good results have been obtained with the hydrogen lines. Although several special forms of quartz tubes have been tried, no satisfactory results have yet been obtained with the metallic lines in which we are especially interested. It is hoped, however, that means will yet be found of producing the brilliant spectra in tubes strong enough to withstand the long exposures which are essential in this work.

ABSORPTION OF OXYGEN AND WATER-VAPOR BANDS.

Observations by Mr. King in the laboratory of the bands A and B of the solar spectrum, ascribed to terrestrial oxygen, and of the water-vapor band *a*, show that these may be seen as absorption bands with a much smaller thickness of air than hitherto has been considered necessary. With a tungsten lamp serving as the source of white light, minimum thicknesses of 7 and 40 meters, respectively, are found to give the A and B bands, while 9.5 meters of air of low humidity show the water-vapor band *a*.

CAUSES OF LYMAN GHOSTS IN DIFFRACTION GRATING SPECTRA.

Mr. Anderson has made a study of the Lyman ghosts shown by three concave gratings in regular use at the Observatory. These are the laboratory 4-inch grating of 1 meter radius, the 5-inch of 15 feet radius, and the 4-inch of 1 meter radius in use on the mountain. The data thus obtained, together with those already published by Lyman, and by Meggers and Kiess, have been used in a discussion of the probable origin of this type of ghosts which will appear in the Journal of the Optical Society of America.

VACUUM THERMO-COUPLES.

Laboratory work on the improvement of vacuum thermo-couples and the application of them to astrophysical problems has been continued by Mr. Pettit and Mr. Nicholson along the lines indicated in the last annual report.

About 20 couples have been constructed for observational work on the mountain, and several piles have been made for laboratory work. The couples used are of the compensated type, with the two junctions brought as closely together as possible. The strips employed are of bismuth and of bismuth alloyed with 5 per cent of tin. The mass of the entire couple as now constructed, including the two tin receivers 0.5 mm. in diameter, is only about 0.025 mg.

These couples are mounted in an evacuated cell of pyrex glass so constructed that they may be removed without destroying the cell or couples. The vacuum increases the sensitiveness of these couples to from 10 to 15 times its value at atmospheric pressure. The effect of the vacuum is slight until a pressure of about 1 mm. of mercury is reached, when the sensitiveness begins to increase rapidly.

A theoretical investigation of the thermal and electrical properties of these couples has been made with the following results: (1) the time required for the current produced by the thermo-couple to come to a maximum after the radiation strikes the receiver is only a few thousandths of a second, and not at all comparable to the period of the galvanometer; (2) the efficiency of the thermo-couple is very low, being in absolute numbers about 1×10^{-6}, and relative to the perfect heat engine, about 1×10^{-2}. From this it appears that if all losses could be nullified, it would be possible to construct a thermo-couple 100 times as sensitive as those now used; (3) the loss by conduction of heat along the strips is greater than the loss by radiation; (4) the gain obtained by placing the thermo-couple at the center of curvature of a hemispherical mirror would be comparatively slight.

The galvanometers generally used with these thermo-couples are of the D'Arsonval type, "Leeds and Northrup high sensitivity." With instruments of from 10 to 60 ohms resistance, scale-distances of as much as 11 meters have been employed. The sensitiveness of the 17-ohm instrument is 3×10^{-10} amp./mm. and is regularly used in the stellar work at a scale-distance of 7 meters. With this arrangement a temperature difference of 0.000001° C. will produce a deflection of 0.2 mm. and the deflection can be measured with certainty to 0.02 mm. A Leeds and Northrup Coblentz-Thompson galvanometer was secured during the year, and after some modifications has been used within an evacuated tube.

REGISTERING MICROPHOTOMETER.

Mr. Pettit and Mr. Nicholson have constructed a thermopile of six junctions to replace the photoelectric cell formerly used in the registering microphotometer, and have investigated its behavior under a variety of conditions.

Since the thermopile can not be compensated for variations in the source of illumination, the constancy of this source is of vital importance. Various lamps were tested, using both alternating and direct current from the generators. Fluctuations of 5 per cent in the radiation over periods of from 0.5 to 2 seconds were found with both currents. A storage battery and straight-filament lamp were adopted finally. For some of the denser plates artificial illumination proved to be unsatisfactory, and for these sunlight has been employed with such success that it has been used for a large part of the work.

The accuracy with which the machine registers the density gradient of a plate depends in large measure on the width of the slit in front of the thermocouple. If this is made too small, however, the effects of the clustering of the silver grains and defects in the film produce false depressions and elevations in the curves. This difficulty has been overcome by placing two parallel plane mirrors in the microscope barrel, which increase the angular aperture of the beam brought to a focus on the thermopile and thus integrate the light from over a greater range on the plate. This arrangement also produces greater galvanometer deflections. The first slit above the plate has been removed and a projected image from a collimator substituted. Through the addition of a multiplying gear, installed in series with the original gear, ratios as high as 500 may be obtained between the microscope stage and registering apparatus.

If the machine is to be operated at a fair speed, a galvanometer of short period should be used in order to avoid distortion due to lag; but, on account of vibrations in the building, it has been found impracticable so far to use a period of less than 4 seconds. It will be necessary to employ some form of the Julius suspension before the short-period galvanometer can be used.

About 50 plates have been taken with the machine for various purposes. A comparison of the density curves of spectral lines obtained with the photoelectric cell and with the thermo-couple shows that considerable improvement has been made. The applicability of the machine to the measurement of radial velocities was tested with a spectrogram of Capella taken with a dispersion of 3 prisms. The curve for a region 8 mm. long near λ4200 was made on the machine with a similar curve for the comparison spectrum. The measurement of these curves with a millimeter scale gave 70.3 km., while the velocity from the spectrogram measured in the usual way was 69.7 km. Curves have also been obtained of the iron line λ6173 in the spectrum of sun-spots to test the reality of the apparent displacement of the *p*-component, and some tests have been made of the use of the machine as a surface photometer for measuring the density of star images and the distribution of density in extended objects, such as the solar corona and nebulæ.

DESIGN FOR A NEW PHYSICAL LABORATORY.

The very crowded conditions of our physical laboratory, and the increasing need of better facilities, have been mentioned in previous reports. No department of the Observatory is more important than its laboratory, which often affords the only possible means of interpreting astronomical results. The absence of any facilities, other than small portable cœlostats, for producing a solar image, is another serious defect of the present laboratory. A new building has therefore been designed, in the hope that funds for its construction may soon become available.

Among the chief features of the projected laboratory is a 60-foot tower telescope, giving a large solar image in the center of a room about 50 feet square, equipped with special arcs, sparks, electric furnaces, and other light-sources. In a subterranean vault beneath this room is a spectrograph of 75 feet focal length, so designed that the collimator can be shortened to 50, 30, or 13 feet, and provided with cameras, for use at various angles with the axis of the collimator, of focal length ranging from 45 inches to 75 feet. This powerful instrument, with other special equipment called for in the scheme, would permit our laboratory investigations to be conducted much more effectively than is now possible.

KILAUEA EXPEDITION.

A joint expedition from the Geophysical Laboratory of the Carnegie Institution and the Mount Wilson Observatory has been planned by Dr. Day for further chemical and spectroscopic examination of the gases issuing from the crater of Kilauea. Mr. Babcock, who will be the representative from the Observatory, has designed and assembled two small rapid spectrographs suitable for use in the field, together with the auxiliary equipment necessary for direct photographs of the spectra of volcanic flames and suitable comparison spectra. Plans were completed for leaving early in June, when a sudden lowering of the lava column removed for the time being all opportunity for making the observations. The volcano has now resumed activity (August) and the expedition is being held in readiness to leave whenever the conditions warrant.

CONSTRUCTION DIVISION.

DRAFTING AND DESIGN.

The work of the department of drafting and design has been carried on during the year by Messrs. Pease, Nichols, and Kinney. Several new instruments have been designed and numerous improvements planned for existing apparatus. The more important of these follow.

For the 100-inch reflector: Concave grating spectrograph; long-focus coudé spectrograph; 3-prism spectrograph with telephoto lenses for use in the red; 12-inch reflecting telescope of the Cassegrain type for use as a finder; changes in 20-foot interferometer beam to admit the use of larger mirrors; large shaper for planing the cylindrical floats.

For the 60-inch reflector: Slitless focal-plane spectrograph for observations of fields of faint stars; redesign of quartz spectrograph for use with a negative lens; modification of counterweight system.

Miscellaneous: Preliminary sketches and model of 50-foot interferometer; 18-inch cœlostat with second plane mirror and driving-clock; designs for apparatus used in the study of the velocity of light and for seismological instruments for Dr. Wood.

As in previous years, the work of preparing drawings and sketches to illustrate the publications of the Observatory has been carried on by the drafting department and has required a considerable amount of time.

OPTICAL SHOP.

In the optical shop Messrs. Kinney and Dalton have carried on a wide variety of work, including the figuring of glass and speculum mirrors, quartz prisms and plates and numerous small lenses for eyepieces. Included among the mirrors are two 18-inch plane mirrors, two 12-inch plane mirrors of pyrex glass, one 12.5-inch concave mirror of 5 feet focal length with a 3.5-inch hyperbolic mirror, the whole forming a system of 20 feet equivalent focal length, four small plane and three small concave mirrors, several speculum plates, both plane and concave. In addition, Mr. Kinney has figured one 60° prism and has refigured several other prisms and mirrors. Mr. Dalton has made several quartz plates for use in interference apparatus and thermo-couple work and a plane-parallel plate of glass for the auroral spectrograph.

GLASS-BLOWING SHOP.

Mr. Pompeo has continued to devote part of his time to the construction of glass and quartz tubes for investigations in the laboratory.

INSTRUMENT SHOP.

The work of the instrument shop, under the immediate direction of Mr. Ayers, foreman, has included much new construction as well as additions and repairs to existing apparatus. Among the new instruments, partially or wholly completed during the year, are the following: long-focus spectroheliograph for experimental purposes, coudé spectrograph, large-aperture focal-plane spectrograph, registering photometer, small Cassegrain spectrograph, three-prism spectrograph for work in the red, apparatus for measuring the velocity of light, 12.5-inch finder for 100-inch telescope, numerous plate-holders, and small attachments.

The section of the 100-inch telescope tube carrying the convex mirror for use in the coudé form of the telescope has been fitted into place, and considerable work has been done on other accessories of this instrument, including the wind screen, shutter mechanism, and observing platform.

RULING MACHINE.

In last year's report it was stated that the accidental error of the ruling machine appeared to have been removed by the improved spacing mechanism made by Mr. Jacomini. As a test of this a small concave grating of 1 meter radius of curvature was ruled and tested. The definition was excellent, showing a satisfactory absence of accidental erorrs, and no ghosts of the Lyman type were found by visual observations. As was to be expected from the known periodic error, the regular or Rowland type of ghost was rather strong.

The screw pivots were investigated by an interference method and a slight eccentricity was found in one of them. This was reduced as far as it was possible to do so, that is, to about 0.000005 inch. Some minor changes were also made in the bearings for the screw, in order to obviate any tendency toward unequal wear of the pivots.

The investigation of the small residual errors in the spacing-wheel is nearing completion.

BUILDINGS, GENERAL CONSTRUCTION, AND TRANSPORTATION.

Construction work on Mount Wilson, under the superintendence of Mr. G. D. Jones, has included a large concrete water-storage reservoir with a capacity of 530,000 gallons, the laying of 1,700 feet of concrete conduit, the addition of a steel roof to the Monastery, and the construction of a temporary laboratory and piers for Professor Michelson's experiments. General repairs have been carried on as usual. Nearly all the Observatory buildings in Pasadena have been repainted during the year.

Mr. Dowd, engineer on Mount Wilson, and Mr. Sidney Jones, assistant engineer, have rewired the 60-inch telescope, laid the electrical cables in the new conduit line, and made numerous additions to the electrical equipment of the 100-inch telescope and other instruments.

The mountain road suffered comparatively little damage from the remarkably severe storms of the past winter, and transportation was carried on with but little interruption, except at times of heavy snowfall. A 1½-ton White motor truck has been purchased for use on the road and has been equipped for both passenger and freight service.

NUTRITION LABORATORY.[1]

FRANCIS G. BENEDICT, DIRECTOR.

Perhaps no one phase of the activities of the Nutrition Laboratory has attracted such general attention as have its extra-laboratory associations. This is evident from the frequent comments which have been made upon the cooperative researches whose results are recorded in the publications of the Laboratory. Such cooperation, if harmonious and successful, has great advantages, especially since it is difficult to include under one roof all of the refinements and experimental juxtapositions that make for successful physiological tests on a large variety of animal organisms.

Our major problems always have been and probably will continue to be found in measurements associated with human metabolism. The age at which humans may be most satisfactorily and economically used for this purpose is that of the college or medical student. Such students have been readily secured for scientific observations at the Laboratory through the courtesy and interest of professors in the neighboring educational institutions. In addition to the nominal payments made to these subjects, they personally derive educational benefits from such studies. In researches with subjects either older or younger than these students, and particularly with groups of individuals, cooperation with other institutions is essential.

For studies of the metabolism of new-born infants, nursing babies, or, indeed, school children, it is not easy to secure suitable individuals and bring them to the Laboratory for observation, for much time must be spent upon the education of the parents. That the Laboratory has been able to make comprehensive studies upon young children is due to the cooperative relations established through Dr. Fritz B. Talbot with the Boston Lying-in Hospital, Massachusetts General Hospital, Directory for Wet-Nurses, and the New England Home for Little Wanderers, all of Boston. To extend the range of these investigations with the younger humans, it was necessary to seek the aid of still another organization, i. e., the Massachusetts Council of Girl Scouts of America, whose cooperation made it possible to study groups of girls from 12 to 18 years of age. Volunteer groups of 18 to 25 young women from Simmons College and the Boston Young Women's Christian Association have also been frequently studied in one of the large respiration chambers.

When the problem of the possible influence of extreme ration curtailment upon the nation became an acute one during the earlier part of the late war, and a fundamental research on undernutrition seemed desirable, it was necessary to select a group of men whose veracity in such studies could under no circumstances be questioned. For this research the Laboratory was particularly fortunate in securing the hearty cooperation of a large group of students from the International Young Men's Christian Association College at Springfield, Massachusetts. These men volunteered their services as subjects and the college authorities offered gratuitously every facility, including the expert counsel of many of its professorial staff.

In an earlier study of a man fasting completely for 31 days, the research was greatly extended in scope by the valued cooperating observations of several members of the faculty of Harvard College and of the Harvard Medical School.

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[1] Situated in Boston, Massachusetts.

Since the Laboratory is located in the vicinity of large hospitals, material for the study of pathological metabolism, especially that of diabetic patients, was secured through the efforts of Dr. Elliott P. Joslin and the facilities of the New England Deaconess Hospital—a cooperation that has been productive of a long series of studies on metabolism in diabetes.

Reliance upon outside resources has been found advantageous not only in studies of human metabolism, where the limitations of the building of the Nutrition Laboratory and of its immediate environment have been recognized as incapable of meeting fully the experimental conditions, but also particularly in several series of observations with the lower animals. The intimate relationship between the temperature of the living cell and its metabolism made a study of cold-blooded animals imperative in interpreting the processes of metabolism, as with these animals it is possible by altering the temperature of the environment to produce a corresponding change in the cell-temperature. As large cold-blooded animals were necessary for the purpose, and these can be found only in zoological parks, a cooperative arrangement for the research was made with the New York Zoological Park. The cell-temperature of birds is normally higher than that of humans, and it was practicable to carry out still another study at the New York Zoological Park on the metabolism of birds of unusual size and shape.

The usefulness of the white rat for feeding experiments makes a study of its metabolism of importance to workers with this animal. Furthermore, the many problems of metabolism incidental to the animal life-cycle may be studied more rapidly with the short life-cycle of rats than with that of humans. But to maintain a good rat colony is of itself a scientific achievement of no mean order; hence the admirably managed rat colony of Professor Henry C. Sherman at Columbia University, New York City, has been employed in a carefully planned investigation upon the metabolism of the white rat in cooperation with Teachers College.

The desirability of maintaining animals upon a constant ration, and possibly upon a single food material, for a much longer period of time than can ordinarily be endured by humans, together with certain very important economic factors in the nutrition of beef animals and particularly in the conversion of carbohydrate to fat, led to an investigation with adult steers, which has been made possible by cooperation with the New Hampshire Agricultural Experiment Station at Durham, New Hampshire. The unusual digestive processes of ruminants warrant a special study of the fate of the various nutrients. Such researches supplement in most vital manner our knowledge of the physiology of humans.

Without exception, these cooperative researches have proved both scientifically and economically among the best of the undertakings of the Nutrition Laboratory. This is probably due to the fact that the cooperative venture in each case was initiated by the Nutrition Laboratory in direct response to a need for information upon special phases of human or animal life—phases which could not well be studied by transporting either animals or humans to the Laboratory building. In every instance the cooperation has resulted in a study which has been beneficial, both scientifically and educationally, to the various cooperating institutions. What might be considered as opportunism, therefore, is actually based upon experimental needs and the carrying out of a carefully prepared plan, the main object of which is to study the fundamental laws governing vital activity, particularly in humans, with supplementary studies on warm-blooded and cold-blooded animals.

An outcome of these cooperative investigations not originally anticipated has been the establishing of two independent metabolism centers by former collaborators in the Laboratory researches, Dr. Fritz B. Talbot, who is continuing the studies on infant metabolism at the Massachusetts General Hospital, and Dr. Elliott P. Joslin, who will carry further the researches upon metabolism of diabetics at the New England Deaconess Hospital. Of interest, also, is the fact that Professor H. Monmouth Smith, formerly an associate of the Nutrition Laboratory, is carrying on metabolism studies at the Massachusetts Institute of Technology. This stimulation to independent research is very desirable, although it has led to the recent loss from the Laboratory staff of two valued laboratory technicians, Miss Mary F. Hendry and Miss Marion L. Baker.

COOPERATING AND VISITING INVESTIGATORS.

Dr. Elliott P. Joslin spent a large part of the year at the Laboratory with a number of his personal assistants in preparing, with the help of members of the Laboratory editorial and computing staff, the third report on diabetic metabolism, which has recently been transmitted to the Carnegie Institution of Washington.

Dr. Howard F. Root, aside from his investigation on metabolism during pregnancy, has continued his cooperation with Dr. Miles in the elaboration of data collected by them on diabetic patients and in the taking of blood samples on subjects used in the research on the effect of alcoholic beverages.

Dr. Eugene C. Howe, of the Department of Hygiene, Wellesley College, has cooperated with Dr. Miles in the securing of a large series of physical measurements on women and in a study of the muscular control of women as represented in their ability to stand motionless.

Professor E. G. Ritzman, of the Agricultural Experiment Station at Durham, New Hampshire, has devoted practically his entire time to the conduct of metabolism studies, with the large respiration chamber, on the energy requirements of large animals. As in former years, the staunch support of Director John C. Kendall has made possible this most profitable cooperative undertaking.

Miss Grace MacLeod, of Teachers College, Columbia University, New York, has superintended the investigations on the metabolism of the white rat, with a special respiration apparatus devised and constructed at the Nutrition Laboratory and installed at Teachers College. The work has the active support and counsel of Professors Henry C. Sherman and Mary Swartz Rose.

The work of the Nutrition Laboratory is attracting the attention of many foreign visitors to this country, with whom most stimulating conferences are frequently held. None have been more helpful to the Laboratory than those with Professors Clemens Pirquet, of Vienna, and Joseph Barcroft, of Cambridge, England. Dr. J. L. Rosedale, of the Institute of Animal Nutrition, Cambridge, England, visited the Laboratory for a short time.

A sojourn of several days by Dr. Eugene F. DuBois, of Bellevue Hospital, New York, was, as is always the case, of great value to the Laboratory.

An increasing number of clinicians have sought advice during the year from the members of the Laboratory staff to obtain first-hand information regarding apparatus and technique for use in measurements of the basal metabolism.

STAFF NOTES.

The debt owed by the Carnegie Institution of Washington to educational institutions for personnel is being rapidly repaid by the fact that members of the staffs of the Institution are being sought by large universities. It has been our particular misfortune to receive the resignation of Professor Walter R. Miles, who, after nine years of most active and fruitful service, not only as an investigator but likewise as an extraordinary administrator, leaves the Laboratory to go to the head of the department of experimental psychology at Leland Stanford Junior University. His studies on the physiology and psychology of the effects of alcohol upon the human organism are some of the most noteworthy contributions from the Laboratory. Indeed, at the moment of writing he is completing several monographs and papers on this subject.

Not only do educational institutions draw from our staff, but the establishment of metabolism centers likewise results in withdrawals from the Laboratory staff. After many years of assistance in the Laboratory, particularly in gas analysis and in the study of the metabolism of young girls, Miss Mary F. Hendry has resigned to accept the charge of gaseous-metabolism work under a former cooperating investigator, Dr. Fritz B. Talbot.

The extraordinary skill shown by Miss Marion L. Baker and her long experience in a wide variety of metabolism researches with both animals and humans have resulted in her accepting a position in charge of the metabolism tests to be made in the metabolism department in the New England Deaconess Hospital independently established by our collaborator, Dr. Elliott P. Joslin.

INVESTIGATIONS IN PROGRESS.

Composition of urine as affected by ingestion of 2.75 per cent alcohol.—The study of the effect of the ingestion of 2.75 per cent alcohol upon the composition of urine eliminated in short periods, which was begun in 1921 by Dr. T. M. Carpenter, has been continued. The determinations of inorganic phosphorus, inorganic sulphates, ethereal sulphates, and total sulphur have been made for a number of control days and days on which 2.75 per cent alcohol was taken. The analyses were made by Mr. Y. Habeshian.

Composition of the urine of fasting steers.—In connection with the metabolism studies upon fasting steers at the New Hampshire Agricultural Experiment Station, urines were collected for 24 hours with two steers for fasts of 5, 7, 10, and 14 days' duration. Dr. Carpenter has made a partial study of the inorganic elements in these urines in that the total sulphur, inorganic sulphates, ethereal sulphates, and chlorides have been determined. The analyses were made by Mr. Habeshian.

Development of a new gas-analysis apparatus.—A new gas-analysis apparatus has been devised by Dr. Carpenter to meet requirements for use in the analysis of respiration-chamber air, when the oxygen deficit and carbon-dioxide content are under 1.50 per cent and the degree of accuracy required is higher than that obtainable with the portable Haldane apparatus. The apparatus has been applied to the determination of the respiratory quotient in the metabolism studies with fasting steers at the New Hampshire Agricultural Experiment Station. Its accuracy has also been tested by the analysis of samples from a stream of air from burning alcohol and acetone whose combustion quotients (CO_2/O_2) are 0.667 and 0.75, respectively. Miss Marion L. Baker has performed most of the analyses.

Standardization of gas-analysis and respiratory-exchange apparatus.—In ordinary respiratory exchange neither the total quantities involved nor the respiratory quotient is constant. In order to simulate these conditions, a method and apparatus have been devised by Dr. Carpenter for producing variations in oxygen consumption and carbon-dioxide output, and in the ratios between the percentage of carbon dioxide and the percentage of oxygen deficit in a continuous current of air. The arrangement can be used for standardizing gas-analysis apparatus and methods of measuring the quantity of expired air. The control substances thus far used have been burning ethyl alcohol and acetone. Mr. E. L. Fox has assisted in this work. In this connection a study has been begun to determine the best form of pipette, the most efficient absorbent for oxygen, and the best method for its preparation. One of the forms of the laboratory type of the Haldane gas-analysis apparatus has been tested with special reference to the analysis of compressed oxygen and oxygen-rich mixtures, such as occur in the Benedict portable respiration apparatus. These tests have been carried out by Miss Mary F. Hendry.

Effect of alcoholic beverages containing 2.75 per cent alcohol by weight.—Dr. W. R. Miles, in the early part of the current year, continued the experiments on the effect of beverages with an alcohol content of 2.75 per cent, which was referred to in the annual report for 1921. Later, with the assistance of Mr. E. S. Mills and Mr. Fox, he elaborated the data for a final report.

Application of Dreyer's physical standards to college women.—The department of hygiene at Wellesley College has for some years made regular and extensive physical examinations of the women in their freshman and sophomore classes. The past year, cooperating with Dr. E. C. Howe of Wellesley College, Dr. Miles was given an opportunity to suggest and introduce measurements in addition to their usual routine. The Dreyer recommendations and standards have been employed with a view to securing data for determining the usefulness of these methods.

Static equilibrium and the motor control of women.—The station test as carried out with the ataxiameter developed in this Laboratory has been used by Dr. Howe and Dr. Miles in making measurements on women subjects, to ascertain the influence of footwear, clothing, bodily position, and other factors on motor control. This work has been in progress at Mary Hemenway Hall, Wellesley College.

Temperature of the skin.—The special technique for measuring the temperature of the skin, which was developed at the Laboratory, has been used in making extensive additions to our data on the temperature of the human skin. These measurements were taken under the clothing and also when the body was nude and exposed to still air, or air moving at different velocities and with different temperature environments. Special attention was given to the cooling effect upon the skin of the vaporization of water and to the comparison of the skin temperature with that taken deep in the body.

Influence of environmental temperature upon metabolism.—With the clothed human individual the temperature environment of the skin is usually fairly constant, although it is by no means uniform in all parts of the body. The influence of altering environmental temperature by exposure of the nude body to air at different temperatures, and particularly the cooling effect of moving air, has been studied in its relation to the basal metabolism. The subject used was the artist's model employed in former years. The details of the measurements were chiefly in the hands of Miss Hendry and Miss Baker.

Metabolism during mental effort.—This complicated problem has been intermittently studied, with special attention to the influence of mental effort upon respiratory rhythm and rate as well as the metabolism. Refinement of technique and methods is progressing, and the problem bids fair ultimately to be attacked with most satisfactory methods.

The insensible perspiration of humans.—The continuous, though slight, loss in weight of the body has been designated as the "insensible perspiration," this being made up in large part of the loss of water by vaporization from the lungs and skin. With the nude subject employed in other investigations, a series of measurements of the insensible perspiration under various conditions of clothing, environmental temperature, and wind velocity have been made by having the subject lie upon a non-hygroscopic bed, suspended on a large balance having a sensitivity with full load of approximately 1 decigram. Simultaneous measurements of the gaseous metabolism and of the trunk and skin temperatures accompanied all of these measurements. The studies were made with the cooperation of Miss Hendry.

The emission calorimeter for humans.—It is believed that in many problems a rapidly changing rate of heat emission from the human body can be measured only by means of a calorimeter of design fundamentally different from any thus far existing. Since at the moment of disrobing there is a profound disturbance of heat-loss, special attention has been devoted to the construction of an emission calorimeter large enough for humans. The development of this apparatus has progressed with the assistance of Miss Baker.

Metabolism of steers during fasting.—From the standpoint of comparative physiology, a knowledge of the metabolism of steers during complete withdrawal of food was necessary, and, indeed, the interpretation of the food needs of these large ruminants can be properly made only by some suitable standard of reference. During the past year two full-grown steers have been subjected to several periods of complete fasting, ranging from 5 days to 14 days. During this time the carbon-dioxide production has been carefully measured and unusual care has been given to the collection and analysis of the excreta. The details of the investigation have been in the hands of Professor E. G. Ritzman, at the New Hampshire Agricultural Experiment Station in Durham, New Hampshire, where the apparatus is installed. Professor Ritzman has been assisted by Miss Helen L. Hilton. The addition of special gas-analysis technique has been possible through the assistance rendered by Dr. Carpenter and Miss Baker, of this Laboratory.

The gaseous metabolism of the white rat.—With the rat colony at Columbia University, in the department of Dr. H. C. Sherman, a cooperative research has been undertaken to study the metabolism of the white rat under various conditions of age, activity, temperature environment, and nutritional plane. A special respiration apparatus, which measures both the carbon-dioxide production and the oxygen consumption of these small animals, has been installed and has been in continuous use throughout the year. The investigation has been in the hands of Miss Grace MacLeod, who has been assisted by Miss Margaret G. Barwis.

Metabolism during pregnancy.—Dr. H. F. Root, assisted by Miss Baker, has made a series of metabolism measurements on a volunteer subject during pregnancy from the third month to several weeks after parturition.

PUBLICITY ACTIVITIES.

In conformance with the general policy of the Carnegie Institution of Washington, special attention has been given this past year to the preparation of several popular articles describing the work of the Laboratory and its practical application. Several lectures have been given by members of the staff before medical societies and the general public. In these lectures motion-picture films of the Laboratory technique have played a rather prominent role. In many of our researches the motion-picture film has been found to be a valuable adjunct for recording scientific events.

PUBLICATIONS.

During the past year, a considerable amount of time has been given to the preparation of two large reports for publication. One of these, *Diabetic Metabolism with High and Low Diets*, is the third monograph on the metabolism of diabetics. The other, *Undernutrition in Steers*, is the first report of the coöperative investigation at the New Hampshire Agricultural Experiment Station. These monographs are now ready for the printer. The following publications have been issued during the year:

(1) *The skin temperature of pachyderms.* Francis G. Benedict, Edward L. Fox, and Marion L. Baker. Proc. Nat. Acad. Sci., vol. 7, p. 154 (1921).

An abbreviated presentation of material published in detail in the *American Journal of Physiology*, vol. 56, p. 464 (1921), and abstracted in the annual report of the Director for 1921.

(2) *Metabolism studies with enemata of dextrose and levulose.* Thorne M. Carpenter. Proc. Amer. Physiol. Soc., Amer. Jour. Physiol., vol. 59, p. 440 (1922).

An abstract of a paper given at the meeting of the Federation of American Societies for Experimental Biology at New Haven, December 1921.

(3) *The relative alcohol content of blood and urine.* W. R. Miles. Proc. Amer. Physiol. Soc., Amer. Jour. Physiol., vol. 59, p. 477 (1922).

An abstract of a paper given at the meeting of the Federation of American Societies for Experimental Biology at New Haven, December 1921, giving the concentration of alcohol appearing in the human blood and urine after the taking of 27.5 grams absolute alcohol in various dilutions.

(4) *Note on electric counters.* W. R. Miles. Jour. Exp. Psychol., vol. 5, p. 76 (1922).

A description of the characteristics of an inexpensive commercial type of electric counter that has various laboratory uses.

(5) *Static equilibrium as a useful test of motor control.* Walter R. Miles. Jour. Indus. Hygiene, vol. 3, p. 316 (1922).

A general review is presented, indicating some previous uses made of the station test. A relatively simple apparatus called, for convenience, an ataxiameter, is described and illustrated. This, as the subject who is being tested tries to stand motionless, automatically accumulates all the anterior-posterior and lateral components of the swaying movements directly in terms of millimeters and provides a convenient method of making the measurement. The quantitative influence of certain anatomical and physiological factors is shown by original data and directions for making such measurements outlined. Results for a long series of measurements are presented and it is shown that station is but slightly improved by training.

(6) *Calories for children.* Francis G. Benedict. New York Med. Jour., vol. 115, p. 126 (1922).

In considering the food needed by children for full activity with best growth, one must know first what is the smallest amount of food necessary to maintain life without providing for activity or growth. Having once determined the minimum food needs, in other words the minimum heat-output of children, one may then study the influence of different factors, such as activity and food ingestion. The Nutrition Laboratory has studied the minimum or basal heat-production of a large number of children from birth to 12 years of age, employing specially constructed respiration chambers for measuring the carbon-dioxide production and oxygen consumption, and thereby indirectly the heat-production. These observations with individual children were subsequently supplemented by observations with groups of children studied at one time in a much larger respiration chamber. With the cooperation of the Girl Scouts of America, measurements were made upon groups consisting of 12 girls each, ranging in age from 12 to 17 years. Thus, data were gradually accumulated with regard to the metabolism of both boys and girls from birth to 12 years of age and the metabolism of girls from 12 to 17 years of age, and thus it has been possible not only to compare these data with regard to differences in the age, weight, and sex of the children, but also to compare them with data secured with adults. One of the most important facts established by this study is the specifically high heat-production during youth. This in part explains the well-known enormous demands for food by active, growing children. The active, growing boy or girl needs practically all the energy intake that can possibly be eaten: (1) for maintenance, and there is a specifically high demand for maintenance; (2) for the normally large physical activity; and (3) for proper growth. Indeed, it may be safely asserted that if digestive disturbances are avoided, it is impossible to overfeed the growing child with good, simple, nourishing food. This paper was given before the Medical Department of the University of Buffalo, New York, June 2, 1921, as the first Harrington Lecture.

(7) *Metabolism during starvation and undernutrition.* Francis G. Benedict. New York Med. Jour., vol. 115, p. 249 (1922).

A study of the influence upon metabolism of complete withdrawal of food was initiated in the chemical laboratory of Wesleyan University, where a large number of short fasting experiments, ranging from 2 to 7 days, were made upon different individuals. Several years later the Nutrition Laboratory made a very extensive study of the metabolism of a man during a 31-day fast. With the onset of the Great War attention was centered upon the question of food conservation, and as a result the Nutrition Laboratory decided to study the problem as to whether it is possible to reduce the food intake in the body so as to permit an appreciable, permanent curtailment in food intake. With the cooperation of the International Y. M. C. A. College at Springfield, Massachusetts, a group of 12 students volunteered as subjects for such a test, and for four months were kept on a diet with an energy content a little more than half of their caloric requirements prior to the test. Another group of 12 students volunteered to serve as a control group, and they were later also subjected to a short period of restricted diet. As a result of these two series of tests, it has been concluded that with adults very considerable drafts upon body material, either as a result of complete withdrawal of food or of prolonged curtailment of the food-supply, may be made without great discomfort and without permanent detriment. We may further say that a moderate curtailment of diet is productive of neither distress nor permanent impairment of the lower animals. It is of special interest to note that one of the most important deductions from these series of observations on humans has been taken up from a practical point of view in the study of animal nutrition. This paper was given before the Medical Department of the University of Buffalo, New York, June 3, 1921, as the second Harrington Lecture.

(8) *Gaseous exchange and physiological requirements for level and grade walking.* Henry Monmouth Smith. Carnegie Inst. Wash. Pub. No. 309 (1922).

This publication covers the results of an extended study of the metabolism and energy requirements of several men during standing and during both horizontal and grade walking. Observations were made also on pulmonary ventilation, respiration-rate, body-temperature, and pulse-rate, the latter by aid of the string galvanometer. Measurements were obtained of the work performed in lifting the body by the heel-and-toe action of walking. The energy expended in transporting one kilogram of body-weight a horizontal meter and for one kilogrammeter of grade work and the efficiency with which this work was performed are reported. A study was made of the response in the pulmonary ventilation, respiration, and pulse as the subject changed from rest to work; also of the time necessary for equilibrium to become reetsablished after the walking had ceased.

It was found that the average standing metabolism for all the subjects was 1.18 calories per kilogram of body-weight per hour, or 28.4 calories per 24 hours. By using their standing requirements as a basis, it was established that with the two main subjects (W. K. and E. D. B.) the increase in energy expended due to horizontal walking was 0.490 and 0.478 gram-calorie, respectively, for each horizontal kilogrammeter of work done. Variations in speed under 80 meters per minute had no effect upon the results, but above that point the energy expended increased proportionately with the increase in speed.

In grade walking the total heat expended increased uniformly per kilogrammeter of work performed at each grade, but was somewhat less when the same amount of work was derived from a high grade and a low speed than when due to a low grade and a high speed. The total outlay was from 12 to 15 gram-calories per kilogrammeter for amounts of work ranging from 300 to 600 kilogrammeters per minute.

From the results of this study it may be said that the net efficiency with which a person can walk up grade is not far from 30 per cent when the work is under 500 kilogrammeters per minute, but with greater amounts of work the efficiency decreases as the work increases.

The pulmonary ventilation and pulse-rate in grade walking increased rapidly as the work performed increased. The respiration-rate also increased. The pulmonary ventilation showed for W. K. and E. D. B. an increase of approximately 350 to 800 per cent when 900 kilogrammeters of work were performed. For a similar amount of work the pulse-rate increased some 90 to 125 per cent and the respiration about 75 to 100 per cent.

In the transition from standing to grade walking, the body appeared to adjust itself to the new demands for increase in the pulmonary ventilation, respiration, and pulse by the end of the third minute of walking, and for the most part in the first 30 seconds. After walking ceased, the recovery was not so prompt, the effect of the walking persisting for a considerable period.

(9) *The comparative concentrations of alcohol in human blood and urine at intervals after ingestion* Walter R. Miles. Jour. Pharm. Exp. Therap., vol. 14, p. 265 (1922).

This research grew out of the question whether the alcohol-content of urine is identical with that of venous blood and if these parallel the intensity of intoxication or alcohol effect following the ingestion of one dose. The Widmark-Nicloux method of alcohol determination has been employed and men representing abstinents, moderate drinkers, and habituals have been tested. During the first 20 or 30 minutes after the ingestion of 27.5 grams absolute alcohol taken in 1,000 c. c. of fluid, the urine alcohol is about the same or a little higher than that in the venous blood; then for one hour or more it is 30 to 50 per cent higher. The same weight of alcohol taken in a concentrated solution produces a definitely higher alcohol concentration in both blood and urine than when taken in a much more dilute solution. The plasma contains a higher alcohol content than the corpuscles in the ratio of about 2 to 1, but the urine is usually higher than the plasma. Subjects habituated to alcohol absorb the 2.75 per cent dose about the same as non-habituated individuals. Changes in the amount of urine per minute do not perceptibly influence the concentration of alcohol in the urine. Both venous blood and urine reach their maximum alcohol concentration together, and while not identical, the urine curve appears very useful for comparison with the time relations of the objective measurements of the alcohol effect on the central nervous system.

(10) *Psychological tests applied to diabetic patients.* W. R. Miles and H. F. Root. Arch. Intern. Med., vol. 30 (1922).

It is well known that diabetic patients frequently complain of poor memory and power of attention, but objective proof of this has been lacking. By certain psychological tests used with such cases, as well as with suitable controls, it was found that diabetic patients with hyperglycemia and glycosuria at the beginning of treatment show a decrement of about 15 per cent in memory and attention tasks. The loss is in amount rather than in quality. With treatment the diabetic improves rapidly in his psychological status, approaching normal. In motor tests for accuracy and quickness of movements, five treated diabetics, each case of long duration, were 20 per cent below normal.

(11) *Three-plane orientation clamp.* W. R. Miles. Jour. Optical Soc. America and Review Sci. Instr., vol. 6, p. 374 (1922).

A combination slow-motion clamp suitable for adjusting writing-points, etc., is described. All three motions are free from back-lash, are practically independent of each other, and, as shown by diagrams, have considerable ranges of movement.

DEPARTMENT OF TERRESTRIAL MAGNETISM.[1]

LOUIS A. BAUER, DIRECTOR.

GENERAL SUMMARY.

STATUS OF OCEAN WORK.

The return of the *Carnegie* to Washington, her home port, on November 10, 1921, after the highly successful two-years' world cruise of 64,044 nautical miles, has already been mentioned in the report for 1921; for the remainder of the year she has been out of commission. Since beginning the ocean work of the Department at San Francisco on August 3, 1905—until June 1908 on the chartered *Galilee*, and since 1909 on the *Carnegie*—17 years have elapsed.

In our early cruises there were disclosed in the mariners' charts giving the compass direction (magnetic declination), errors amounting to 3°, 5°, 10°, and even 16° in certain parts of the oceans, the errors often at times continuing in the same direction for several thousand miles. Equally serious errors were found in the magnetic charts showing the inclination or dip of the magnetic needle and the strength of the Earth's magnetic field; the errors in inclination not infrequently amounted to over 10° and the values of the Earth's magnetic intensity were found erroneous at times by amounts reaching and even exceeding 10 per cent.

When it is recalled that nearly three-fourths of the Earth's surface is embraced by the ocean areas, it will be readily understood that lack of accurate data for this portion of the globe has greatly retarded the settlement of several of the chief problems of the Earth's magnetism. This unfortunate state of affairs is now passed, thanks to the accumulated data obtained since 1905, both on sea and land, under the auspices of the Carnegie Institution of Washington and of other organizations. With the aid of the data supplied promptly from time to time to the leading hydrographic establishments, a steady improvement in the magnetic charts has resulted.

While there are still some large ocean areas, 500,000 to 1,000,000 square miles, within which no recent accurate magnetic observations have been made, it is believed that the chief conclusions regarding the general constitution of the Earth's magnetic field which may result from an analysis of the existing data now in progress will not be seriously affected.

However, the Earth's magnetism is subject to ceaseless change, the laws of which can not as yet be precisely formulated. We may determine from our analysis of the existing data numerical quantities, the so-called "magnetic constants," which will define at some particular time, for example, a mid-date between 1905 and 1921, the precise constitution and distribution of the Earth's magnetic field, and will characterize, in a general way, the magnetic and electric systems within and outside the Earth producing the magnetic forces observed on the surface. But it does not seem likely that we shall be able to determine from these "magnetic constants" for any particular date the *origin* of the composing magnetic and electric systems. It is believed, however, that some clues as to origin, or causes, will be obtained from the character of changes which those "magnetic constants" will be found to undergo from time to time. Those changes, as experience has shown, are of sufficient amount to require the reissue of magnetic charts, even for purely practical purposes, preferably at intervals not exceeding five years. Judging from past experience, theories of the Earth's magnetism which are advanced without adequate consideration of the conditions which must be fulfilled to account for its continual changes are not likely to prevail. Hence for some time at least and for the benefit of successive generations, we must supplement our studies by continued observation of magnetic and electric fluctuations.

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[1] Address, Thirty-sixth Street and Broad Branch Road, Washington, D. C.

Important as has been the ocean magnetic work, almost equally so, especially for theoretical studies, have been the results obtained at sea pertaining to atmospheric electricity and atmospheric refraction. The "electric" results, obtained chiefly aboard the *Carnegie*, will have, it is believed, an important bearing on theories of the origin of atmospheric electricity.

TABLE 1.—*Summary of ocean magnetic work of the Galilee and the Carnegie, 1905–1921.*

Vessel and cruise.	Days.	Nautical miles.	Observed values.			Average time-interval (days).			Average distance apart (miles).			Average day's run in nautical miles.
			Declination.	Inclination.	Horizontal intensity.	Declination.	Inclination.	Horizontal intensity.	Declination.	Inclination.	Horizontal intensity.	
Galilee.												
Cruise I, 1905.....	92	10,571	74	58	59	1.2	1.6	1.6	143	182	179	115
Cruise II, 1906....	168	16,286	95	88	91	1.8	1.9	1.8	171	185	179	97
Cruise III, 1906–08	334	36,977	156	169	171	2.1	2.0	2.0	237	219	216	111
Totals for *Galilee*.	594	63,834	325	315	321	1.8	1.9	1.9	196	203	199	107
Carnegie.												
Cruise I, 1909–10..	96	9,600	98	68	69	1.0	1.4	1.4	98	141	139	100
Cruise II, 1910–13.	798	92,829	858	648	643	0.9	1.2	1.2	108	143	144	116
Cruise III, 1914...	84	9,560	108	81	80	0.8	1.0	1.0	89	118	119	114
Cruise IV, 1915–17.	487	63,401	867	480	479	0.6	1.0	1.0	73	132	132	130
Cruise V, 1917–18..	122	13,786	224	116	116	0.5	1.1	1.1	62	119	119	113
Cruise VI, 1919–21.	485	64,044	833	439	439	0.6	1.1	1.1	77	146	146	132
Totals for *Carnegie*	2,072	253,220	2,988	1,832	1,826	0.7	1.1	1.1	85	138	139	122
Totals, *Galilee* and *Carnegie*	2,666	317,054	3,313	2,147	2,147	0.8	1.2	1.2	96	148	148	119

Table 1 brings up to date the summary of the ocean magnetic work of the *Galilee* and the *Carnegie*, 1905–1921. From the bottom row of figures, giving the totals for the cruises of the *Galilee* and the *Carnegie*, 1905–1921, 317,054 nautical miles, or 365,103 statute miles, it will be seen that the magnetic observations have been made practically daily throughout the entire period, and that the average distance apart for the various magnetic elements is from 96 to 148 nautical miles. A comparison of the separate totals for the *Galilee*, 63,834 nautical miles, and the *Carnegie*, 253,220 nautical miles, shows the great improvement resulting when a specially constructed non-magnetic vessel like the *Carnegie* could be utilized and as the instrumental appliances and observational methods were steadily improved in accordance with experience gained.

FUNDAMENTAL PROBLEMS OF THE EARTH'S MAGNETISM AND ELECTRICITY AND MOST EFFECTIVE METHODS OF RESEARCH.

In order to have clearly in mind once more the purposes and aims of the Department of Terrestrial Magnetism, a conference was held at the Department's Laboratory in Washington on January 20, 1922, with the prime view of determining what modifications, if any, in the original plan of work, outlined in the Year Book of the Institution for 1903, pages 203-212, might advantageously be made at present. The following persons, who had been specially invited by the Director of the Department, after consultation with the President of the Institution, Dr. John C. Merriam, took part in the conference: Dr. C. G. Abbot, Assistant Secretary of the Smithsonian Institution, Washington, D. C.; Mr. Gano Dunn, President of the J. G. White Engineering Corporation, New York City; Captain R. L. Faris, Assistant Director of the U. S. Coast and Geodetic Survey, Washington, D. C.; Mr. G. W. Littlehales, Hydrographic Engineer of the U. S. Hydrographic Office, Washington, D. C., and Dr. Augustus Trowbridge, Professor of Physics, Princeton University. There were also present, besides the Director of the Department, Dr. Merriam and the Assistant Director, Mr. Fleming. Dr. R. A. Millikan had likewise been invited to the conference, but, owing to pressing duties, was unable to be present. Mr. Fleming acted as secretary.

The members of the conference, upon arrival at the Laboratory, first made a general inspection of the various buildings and equipment. The development of instrumental appliances was described and illustrated by an exhibit, in the Standardizing Magnetic Observatory, of magnetic-survey and observatory instruments, chiefly designed and constructed by the Department. There were shown particularly one of the Department's latest designs of magnetometer-inductor for field work and the recently constructed sine galvanometer. The Experiment Building was then visited, and brief description was given by Dr. Barnett of his investigations concerning magnetization by rotation and the converse problem. After examining the instrument-shop and main laboratory, the temporary atmospheric-electric house on the deck of the Laboratory was inspected, and the apparatus and methods were briefly described by Dr. Mauchly. The members of the conference then met in the Director's room for a review and discussion of the following topics:

TOPICS REVIEWED AND DISCUSSED DURING CONFERENCE.

1. Establishment of the Department (April 1, 1904):
    - *a.* Reduction bureau. (International polar work. Incomplete and unhomogeneous data. Found best to start afresh.)
    - *b.* Chief problems outlined in original project. (See 2, 3, 4, 5, and 9.)
2. Magnetic survey of Earth (begun 1905):
    - *a.* Land work. (Progress and present status. Unexplored regions. Secular changes.)
    - *b.* Ocean work. (Pacific Ocean. Map of cruises of the *Galilee*, 1905-1908, and the *Carnegie*, 1909-1921.)
    - *c.* Difficulties of ocean work overcome. Instruments devised. Perfection reached.
    - *d.* Future work of the *Carnegie*. (Additional data. Secular changes. Local disturbances. Electric and other auxiliary work.)
    - *e.* Special expeditions. (Eclipse work, polar expeditions, etc.)
    - *f.* Correlation with work of other organizations. (International cooperation.)
    - *g.* Reduction to same basis and common epoch, and prompt publication.
    - *h.* Relations between local magnetic disturbances, gravity anomalies, and geological formations.

3. Electric survey of Earth (begun 1907):
    - *a.* Land.
    - *b.* Ocean.
    - *c.* Diurnal and other variations; effects during eclipses; etc.
    - *d.* Observations in upper levels (electric disturbances; "statics"; etc.).
    - *e.* Earth-currents (disturbances in telegraphic transmission).
    - *f.* Polar lights.
4. Observatory work (terrestrial magnetism, atmospheric electricity, earth-currents, polar lights, etc.; present and desirable distribution of recording stations; magnetic storms, perturbations, pulsations, relations with solar activity, etc.). The Department of Terrestrial Magnetism has at present in operation two magnetic observatories: Watheroo, Western Australia, and Huancayo, Peru.
5. Magnetic observations in upper levels and ocean depths:
    - *a.* Infinite distributions possible on basis of surface observations alone.
    - *b.* Bearing on aviation problems.
    - *c.* Local disturbances and variations. (See also 2*h*.)
6. Cosmic relations.
    - *a.* Solar and planetary magnetism.
    - *b.* Relations between solar activity, terrestrial magnetism, and terrestrial electricity.
7. Laboratory investigations (magnetism in general; development of instruments and methods for investigational and observational work; experimental reproduction of observed cosmic magnetic and electric phenomena).
8. Analysis and causes of the Earth's magnetic and electric fields:
    - *a.* Results of previous analyses.
    - *b.* Line-integrals. Is action on magnet wholly a couple?
    - *c.* Rôle of the variations (analyses and causes).
    - *d.* Possible bearings on the properties and constitution of matter, and cause of gravitation.
    - *e.* See 2*h*, 5*a*, and 5*c*.
9. General aim of work as announced in 1903. "To investigate such problems of world-wide interest as relate to the magnetic and electric condition of the Earth and its atmosphere, not specifically the subject of inquiry of any one country, but of international concern and benefit."
10. Funds and name of department.

Although the conference was limited to one day, on account of other pressing engagements of some of the members, its main purposes were accomplished. The Institution and the Department were fortunate in the selection of those who had been invited to the conference. Suggestions and recommendations were made which will prove beneficial in the future work of the Department and serve as a further stimulus in our endeavors. Brief consideration was given to the question of a more comprehensive or more elucidative name for the Department than its present one, but no definite conclusion was reached.

MAIN CONCLUSIONS AND RECOMMENDATIONS OF CONFERENCE.]

A. Magnetic and Electric Survey of the Earth:

a. It was the consensus of opinion that the magnetic and electric survey of the Earth should be continued; however, in view of the satisfactory progress made since 1905, the future work need not be so intensive, but should be planned so as to obtain additional data in regions where urgently required, above all, as to the secular changes of the Earth's magnetism, which may play an important rôle in the theoretical solution of some of the outstanding problems. Detailed surveys of locally disturbed areas on land and sea may reveal suggestive relationships with gravity anomalies and geological formations.

b. In view of the theoretical importance of magnetic and electric observations in upper levels of the atmosphere (topics 3*d* and 5), it was considered highly desirable to make arrangements for such observations as soon as facilities and conditions permit.

B. Observatory Work:

Because of the unsatisfactory distribution of magnetic observatories in the Southern Hemisphere, it was considered highly important that the complete program of work in terrestrial magnetism, atmospheric electricity, earth-currents, and allied observations at the two magnetic observatories (Watheroo, Western Australia, and Huancayo, Peru) be fully carried out. Further relations with other geophysical and cosmical phenomena, such as polar lights, "statics," earth-currents, solar activity, etc., may be disclosed. The intensive study of instantaneous, or short-period, perturbations at widely separated observatories, making use of available wireless stations for obtaining the desired accuracy in the time element, was specially recommended.

C. Laboratory Investigations:

It was thought essential that laboratory investigations, such as are briefly enumerated under Topic 7, be conducted concurrently with the observational work in the field and at the observatories. Besides the experiments on magnetism in general, now in progress, it was considered desirable to continue the investigations relating to the existence of vertical electric currents and the Earth's precise action on a magnet. The possible effect of high pressure on the critical temperature of magnetization was also considered a problem which may have important bearings on some of the topics.

D. Theoretical Studies:

The analyses and theoretical studies outlined under topic 8, it was thought should be vigorously continued. It was suggested in this connection that it would be highly desirable to make provision, as soon as conditions permitted, to add to the Department's staff a well-trained mathematical physicist to assist the Director in his theoretical studies.

The year's work of the Department was planned, as far as circumstances permitted, to put into effect the conclusions and recommendations of the conference.

Regarding the personnel of the Department and the duties assigned to each member during the year, reference may be made to the summary on page 282.

INVESTIGATIONAL WORK IN WASHINGTON.

The general investigational work, theoretical and experimental, conducted during the year in the Department's laboratory at Washington by the Division of Investigational Work, under the Director's charge, was as follows:

TERRESTRIAL MAGNETISM AND ELECTRICITY.[1]

(1) *Line-integrals of the magnetic force.*—Additional computations have been made since those reported upon last year bearing upon one of the chief outstanding problems in terrestrial magnetism. The question is whether any appreciable percentage of the magnetic forces observed on the Earth's surface may have to be ascribed to electric currents passing perpendicularly through the surface, from the atmosphere into the Earth, and *vice versa*, or to some cause whose effects are equivalent to vertical currents and thus cause a slight non-uniformity in the terrestrial magnetic field. The results for four large ocean areas inclosed by the *Carnegie's* tracks 1909–1913, two of the areas being in the North Atlantic Ocean, one in the Indian, and one in the Pacific Ocean, all accord with our previous determinations in regard to the direction and general magnitude of indicated vertical electric currents. They also show a consistent and possibly a significant geographical distribution in magnitude as well as algebraic sign. At the Rome meeting in May of the International Section of Terrestrial Magnetism and Electricity, Sir Arthur Schuster and Sir Frank Dyson informed the Director of similar results

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[1] From the report of Louis A. Bauer and W. J. Peters.

obtained by them independently. Schuster's results were derived from line-integrals of the magnetic force in Great Britain as based on the latest magnetic survey by G. W. Walker, and Dyson's results depend on the world magnetic charts for 1922, based on the latest observations, chiefly those of the *Carnegie* and the Department's land expeditions. It is hoped that before long some experimental investigations may be undertaken for further testing this important question. The combined results would indicate that, on the average, about 2 per cent of the Earth's magnetic field is involved in the production of vertical electric currents. (For further information, see pp. 296–297.)

(2) *Results of recent earth-current observations.*—Preparatory to the initiation of observational work on earth-currents at the Watheroo Observatory, the Director, assisted by members of his staff, undertook a discussion of the most extensive available series of observations, namely the eleven-year series, 1910–1920, obtained at the Observatorio del Ebro, Tortosa, Spain. One of the chief conclusions reached was that the resultant electric current flowing in the Earth's crust, as observed at the Ebro Observatory, was approximately in the direction from the Magnetic North Pole towards south-southeast, hence towards the equator (see pp. 290–291). It will be a matter of no little interest to know whether at a station in the Southern Hemisphere—at the Watheroo Observatory, for example—the earth-current will be reversed in direction to that in Spain, so as to flow also *towards* the equator. If so, then we shall have another clue bearing on the question raised under (1). It is rather interesting in this connection that such computations as we are able to make on the basis of the existing data would indicate that the strength of the electric currents found circulating in the Earth's crust is of about the same order of magnitude as those apparently disclosed by the results reported upon under (1). Concurrently with the Director's discussion of existing earth-current data, an experimental study was assigned to Mr. Gish, in consultation with Dr. Mauchly, regarding the best methods and instruments for earth-current measurements.

The results of the investigations by the Director and Mr. Gish indicated that it would be well worth while trying out at the Watheroo Observatory whether satisfactory data may not be obtainable from specially constructed earth-current lines, not exceeding 1 to 2 miles in length. (See pp. 300–301.) For the proper interpretation of the results obtained from the potential-gradient observations, it appears also desirable to make provision for observations regarding the electric conductivity of the soil. Investigations on earth-currents, such as here outlined, are of interest not alone to students of the Earth's magnetism and electricity, but also to those who are investigating the causes of disturbances in telegraphic transmission, the causes of corrosion of water and gas mains, and electrical methods of locating ore bodies.

(3) *Relations between the Earth's magnetic and electric phenomena and solar activity.*—The Director's investigations, based on the published eleven-year series of observations at the Ebro Observatory, have furnished some further confirmation of results given in previous reports. There would hardly seem any question now that the normal electric condition of the Earth and of the atmosphere is dependent upon the precise state of activity of the Sun, and hence varies during the sun-spot cycle, just as magnetic phenomena have

long been known to do. Further efforts have been made in the course of these investigations to determine the most effective measures of activity of magnetic, electric, and solar phenomena. (See pp. 289–292.)

(4) *Dynamic and tilting deviations.*—This is partly a theoretical and partly an experimental investigation conducted by Mr. Peters with the view of ascertaining what appreciable errors may be introduced in magnetic measurements at sea as the results of the effects of the ship's motions on magnetic systems whose center of gravity may or may not fall in the axis of support. Besides their bearing on our ocean work, the results of the investigation will be of importance in the design of instruments and study of the best method of observation of the magnetic forces in upper levels of the atmosphere. (See p. 306.)

(5) *Publication work.*—Good progress has been made with various papers for Volume V, "Researches of the Department."

EXPERIMENTAL WORK IN MAGNETISM.[1]

(1) *Magnetization by rotation.*—The experiments have been conducted as in previous years by Dr. Barnett, in the specially constructed Experiment Building on the Department's site at Washington. A long-suspected error in the 1917 experiments by the magnetometer method has been successfully eliminated, so that the results derived from the two independent methods (electromagnetic induction and magnetometer) are now in satisfactory agreement (see p. 284). Dr. Barnett interprets his results to date as follows:

> "Rotating any ferromagnetic substance investigated at one revolution per second is equivalent to placing it in an axial magnetic field with intensity —3.5×10^{-7} gauss, within about one part in ten. This result would be expected if a single type of negative magneton, with ratio of angular momentum to magnetic moment equal to m/e, one-half that of a ring of electrons, were responsible for ferromagnetism. Abraham showed in 1903 that a superficially charged Lorentz electron in rotation has the moment and the momentum giving this ratio. If a ring of electrons is chiefly responsible for ferromagnetism, positive magnetons also participate, as stated before."

(2) *Theories of magnetism.*—As a member of the National Research Council's Committee on Theories of Magnetism, Dr. Barnett prepared a paper on "The Angular Momentum of the Elementary Magnet." (See abstract, p. 285.)

(3) *Electrodynamics of moving bodies.*—Dr. Barnett has continued his theoretical investigations under this head, and has contributed three papers to the American Physical Society. (See abstract, p. 286.)

(4) *Sine galvanometer.*—Remaining details were completed for the monograph which has appeared in Volume IV, Researches of the Department, and a paper was presented on the completed instrument at the Toronto meeting of the American Physical Society, December 1921.

EXPERIMENTAL WORK IN TERRESTRIAL ELECTRICITY.[2]

(1) *Atmospheric-electric apparatus for observatories and special expeditions.*—On the basis of studies and experiments made, it was possible further to standardize and perfect the instruments for atmospheric-electric observations

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[1] From the report of the chief of the section, S. J. Barnett.

[2] From the report of the chief of the section, S. J. Mauchly.

at the Department's various observatories. Special attention was paid at first to the apparatus required at the Watheroo Observatory in Western Australia, and later for the Huancayo Observatory in Peru. The association with the Department, during the period October 1921 to March 1922, of Dr. H. U. Sverdrup, in charge of the scientific work of the Amundsen Arctic Expedition, provided a unique opportunity to arrange for greatly desired atmospheric-electric data in the polar regions. Accordingly, a special equipment was devised for use under the conditions likely to be encountered by the expedition. Arrangements were also completed for special observations at the Watheroo Observatory in connection with the total solar eclipse of September 21, 1922. The experimental observatory on the deck of the Laboratory at Washington was continued in operation, not alone for obtaining continuous records of changes in the electric condition of the atmosphere, but also to assist in determining upon the best instrumental appliances. Regarding a rotary slide-wire devised by Dr. Mauchly for producing uniform variation in potential differences, see abstract, page 302.

(2) *Reduction of atmospheric-electric observations made aboard the Carnegie and at Washington.*—The results of these observations are proving of unusual interest and will form an important contribution to the subject of atmospheric electricity.

(3) *Methods and equipment for earth-current observations.*—Mr. Gish, as already stated on page 271, was assigned to the section to undertake experimental work bearing on best methods and instruments for earth-current observations, with special reference to the installations now being made at the Watheroo Observatory. In the furtherance of these studies, leading scientific men were consulted and valuable suggestions were thus obtained. As a result of these conferences and the investigations made at Washington and at Cheltenham, Maryland, decision was reached that the best type of earth-current line would seem to be one having "subterranean lines consisting of leaded rubber-covered cable laid about 18 inches deep in insulating conduit." The precise type of installation decided upon for the Watheroo Observatory is described on pages 300–301.

(4) *Polar-light investigations.*—Preliminary studies bearing on this subject have been continued, and a progress report was presented at the annual meeting of the American Geophysical Union, March 1922. (See abstract, p. 305.)

OBSERVATIONAL AND ADMINISTRATIVE WORK.

Mr. J. A. Fleming, who has been connected with the Department since its establishment in 1904, was appointed on January 1, 1922, to the new position of "Assistant Director for Observational and Administrative Work."

Besides the important land expeditions in Africa, Asia, Australasia, Europe, North America, South America, and on islands of the Atlantic and Pacific oceans, briefly described below, special mention may be made of the safe return in September of the MacMillan Baffin Land Expedition, with which the Department has cooperated, the assigned program of scientific work having been successfully carried out.

The Department's magnetic observatory at Watheroo, Western Australia, by the end of the year will be the most completely equipped observatory in the Southern Hemisphere for investigations relating to terrestrial magnetism, atmospheric electricity, and earth-currents. The continuous registration of the magnetic fluctuations was begun at the Huancayo Magnetic Observatory in Peru, and the installations for the atmospheric-electric observations are under way.

Along with the observational work and numerous investigations connected therewith, good progress has been made with the computational and the publication work. During the period of the association with the Department of Dr. H. U. Sverdrup, in charge of the scientific work of the Amundsen Arctic Expedition, it was possible to complete the reductions of the magnetic observations obtained by the expedition from 1918 to 1921 on the Northeast Passage. A preliminary publication by Messrs. Duvall and Sverdrup of the chief results of this very valuable work has appeared in the March–June 1922 issue of *Terrestrial Magnetism and Atmospheric Electricity* (see pp. 307–308).

The force of the instrument-shop is still heavily taxed with meeting the varied demands. In consequence, it has not been possible to respond to the numerous requests received, especially from foreign governments, for instruments of our design. However, assistance has been rendered to various organizations and makers, at home and abroad, by supplying copies of drawings of our instruments and of specifications.

For abstracts of publications by members of the Division, see pages 283–309.

The following abstracts from the reports by Mr. Fleming and his chief assistants will give some idea of the extensive work accomplished by the Division of Observational and Administrative Work.

OCEAN WORK.[1]

Since the completion of the *Carnegie's* cruise (No. VI) at Washington, on November 10, 1921, the vessel has been out of commission and under the care of Mr. Albert Erickson, first watch-officer. By courtesy of the Commissioners of the District of Columbia, free use of the old ferry wharf was given until June 15, 1922; since then the *Carnegie* has been berthed on the south side of the Washington-Colonial Beach Steamboat Company's wharf.

Certain essential repairs of the auxiliary power plant were made during December and January by Mr. C. E. Leyer, engineer.

On July 10–11, 1922, as thorough a survey as possible, without placing the vessel in dry-dock, was made by a competent inspector. It was found that dry-rot had developed to such an extent, particularly in the portion not renewed when the vessel was overhauled in 1914, as to require extensive repairs before it will be safe to undertake another lengthy cruise. Late in October the vessel was housed with canvas on wooden, non-magnetic framing to protect her more effectively while she continues out of commission and to reduce the expense of maintenance.

The closing measurements and comparisons of instrumental appliances, which were required for the final reduction of the ocean observations, were satisfactorily completed. Special tests of some nautical instruments were undertaken, and good progress has been made with the preparation for publication of the final results of the ocean work during the cruises 1915–1921.

The *Carnegie*, while in port at Washington, has had many distinguished visitors.

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[1] From the report of the chief of the section, J. P. Ault.

LAND MAGNETIC SURVEY.[1]

Magnetic changes.—The endeavor was made, while the *Carnegie* was out of commission, to concentrate the work of the available observers upon securing magnetic observations in land areas where further information was urgently needed, especially with regard to secular changes. A sufficient time had elapsed to make it worth while to repeat observations at a carefully selected number of our earlier established stations and thus determine the magnetic changes which had occurred during the elapsed interval. These magnetic changes, as accurate observations have multiplied, are proving to be of a more complicated character than at times realized. Similar experience is encountered by other magnetic services. Thus recent magnetic observations of the United States Coast and Geodetic Survey have shown that the rate of change of the magnetic declination, or direction of the compass, "has varied so much recently that values carried forward from 1915 are in some cases not dependable."

Along with the desired repeat observations, important magnetic data were likewise obtained in regions requiring filling in. The main expeditions during the year were as follows:

1. *Africa.*—Mr. W. C. Parkinson made comparisons of the instruments used by him with those of the Helwan Observatory, Egypt. While en route to Spain for further observatory comparisons, he reoccupied stations of the Department in Egypt, Sinai Peninsula, Tunisia, and Algeria; observations were made also at Bouzareah Observatory near Algiers.

2. *Asia.*—Observer Frederick Brown, while en route from Australia to China, reoccupied Department stations and established a new station at Singapore. During February to July 1922, he made weekly observations at the station of the Department on the grounds of the Canton Christian College, Canton, China. Resuming his field work on July 11, he made repeat observations at six C. I. W. stations in China and comparisons of his instruments with the electric magnetometers of Professor Watanabe and with the standard observatory instruments at Kakioka, Japan. He then proceeded to Washington, where he arrived early in September.

Dr. P. H. Dike, of the staff of Robert College, Constantinople, formerly an observer of the Department, was engaged temporarily for three months from the first of June, making magnetic observations on expeditions into Asia Minor, Syria, and the islands of the eastern Mediterranean.

Mr. W. C. Parkinson reoccupied the C. I. W. station at Jidda, Arabia, and established new stations at Yambo, El Wedj, and Jidda, in Arabia. Dr. H. U. Sverdrup (Amundsen Expedition) reoccupied the station at Kain-ge-skon, Siberia.

3. *Australasia.*—Mr. Frederick Brown, accompanied by Assistant Observer J. Shearer of the Watheroo Magnetic Observatory, during the early part of November 1921 reoccupied three C. I. W. stations in Western Australia and established a new station at Bunbury. Mr. Brown left Fremantle November 9, for China, occupying en route four additional C. I. W. stations and one new station in Western Australia. Mr. Shearer spent the remainder of November reoccupying Department stations at Northam, Southern Cross, and Coolgardie, returning to Watheroo on November 26.

Observer Donald G. Coleman, at the conclusion of his work in the Fiji Islands, while en route to Melbourne, occupied four stations in New South Wales. During February Mr. Coleman compared his instrument with those of the Melbourne Observatory and at the Observatory's new site, Toolangi, and assisted Dr. Baldwin in the transfer from the old site and in mounting of instruments at the new site. He then occupied 10 stations in New Zealand. At the conclusion of his work in the Pacific Islands in July, he returned to Sydney via New Zealand, reoccupying the Auckland station en route and about 10 stations in New South Wales and Queensland. During the total solar eclipse of September 21, 1922, he made observations at Coongoola in accordance with a special program.

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[1] From the report of the chief of the section, H. W. Fisk.

The cooperation of the Department with the Government astronomer of South Australia was continued during the year. Mr. A. L. Kennedy, chief assistant at the observatory, made special magnetic observations during the total solar eclipse of September 21 at the C. I. W. station Cordillo Downs in South Australia, and while en route to and from the eclipse station, obtained secular-variation observations at ten C. I. W. stations northeast of Lake Eyre.

Absolute observations, as well as continuous photographic registrations, were made throughout the year at the Watheroo Magnetic Observatory (see p. 277).

4. *Europe.*—Dr. Dike in June made a series of observations at the C. I. W. station Rumeli Hissar near Robert College, Constantinople, and reoccupied early in July C. I. W. stations in Greece and on the island of Crete. Returning to Constantinople the first part of September, he completed his field work by observations at Rumeli Hissar.

Magnetician W. C. Parkinson, while en route to Washington from the Watheroo Magnetic Observatory, from March 30 to the latter part of September, secured an extensive series of observatory intercomparisons of standards at the following observatories: Ebro, near Tortosa, Spain; San Fernando, near Cadiz, Spain; Coimbra Observatory, Portugal; comparison of standard instruments of the Italian Survey at Terracina, Italy; Val Joyeux, near Paris, France, Potsdam, Germany; De Bilt, Holland; Rude Skov, Denmark; Sodankylä, Finland; Greenwich, England; Uccle, Belgium; Eskdalemuir, Scotland; and Kew, England. (The expenses on account of the work at Uccle were paid by the Section of Terrestrial Magnetism and Electricity of the International Union of Geodesy and Geophysics.) During September Mr. Parkinson also obtained comparisons at Teddington between his magnetometer and the Schuster-Smith magnetometer. Between April 30 and May 11, 1922, Mr. Parkinson assisted the Director at the Meeting of the International Union of Geodesy and Geophysics at Rome.

5. *North America.*—Observers J. W. Green and W. A. Love reoccupied during June magnetic stations at Waycross, Georgia, and Miami, Florida, while en route to the Bahamas and West Indies.

The MacMillan Baffin Land Expedition, with which the Department cooperated (see p. 327 of last annual report), returned to Wiscasset, Maine, on September 12 after an absence of almost 14 months. In addition to the successful observatory work done at the winter-quarters at Bowdoin Harbor (see p. 278), 28 magnetic field-stations were established, as follows by Messrs. G. D. Howell, of the Expedition staff, and R. H. Goddard, of the Department staff: Baffin Land, 21 (chiefly along the southern and southwestern coasts and at 2 points on the northern coast); Labrador, 5; Newfoundland and Nova Scotia, one each. Four of these stations were occupied also a second time during the course of the Expedition.

Plans for further cooperation with Captain Amundsen's "*Maud* Expedition" were made, and instrumental equipment and miscellaneous appurtenances were provided. The expedition left Seattle on June 3 and Nome on June 29, for the expected drift across the Polar Sea. Magnetic observations were made in July at Deering, Alaska.

6. *South America.*—Upon the conclusion of his work in the West Indies, Mr. J. W. Green reoccupied the C. I. W. station at Caracas, Venezuela, and then proceeded upon an expedition westward to the Colombian boundary and eastward along the Caribbean coast, occupying stations at intervals, before taking up a more extended program of work in Brazil, Argentina, and other South American countries.

Mr. W. A. Love proceeded from the West Indies to South America, where he reoccupied stations chiefly in Colombia, Ecuador, and Peru. Upon the completion of this work it is expected that he will take up the reoccupation of C. I. W. stations in Central America.

Absolute magnetic observations, as well as continuous photographic registrations, have been obtained since March 1, 1922, at the Huancayo Magnetic Observatory (see p. 277).

7. *Islands, Atlantic Ocean.*—Observer H. R. Grummann made observations at 9 stations on the island of St. Thomas, St. Croix, St. Kitts, Antigua, Guadeloupe, Dominica, St. Lucia, and Martinique.

Observer J. W. Green, accompanied by Observer W. A. Love, reoccupied old stations and established new ones at 12 points on the Bahama Islands. On August 9 the party left Nassau and arrived at Havana, August 12, where they reoccupied C. I. W. stations Havana and Pinar del Rio. Mr. Green then proceeded to Haiti and Dominican Republic, where he established about 11 stations at the principal ports and accessible inland points; en route he reoccupied the C. I. W. station at Kingston, Jamaica. During late August to October, Mr. Love worked independently in Cuba and Jamaica, occupying 12 stations, most of which had been previously occupied by observers of the Department.

Magnetician H. W. Fisk, accompanied by Observer J. T. Howard, made special studies of the interesting magnetic anomaly in Bermuda. The most important questions in connection with these studies are whether the existence of the anomaly affects the rate of secular variation, whether any change in the diurnal-variation curves can be ascribed to the presence of a disturbing force, and the depths, positions, and composition of the disturbing masses. In addition to repeat observations at the five primary C. I. W. stations of 1907, about 100 auxiliary stations were established for charting the magnetic anomaly and six 12-hour series of diurnal-variation observations were made for each of the three magnetic elements.

8. *Islands, Pacific Ocean.*—Observer Donald G. Coleman continued his work in the Pacific islands, reoccupying stations previously established by the Department, as well as securing distribution data at a number of new stations. In spite of some difficulties encountered in getting about among the various groups, he occupied 10 stations in the Solomon Islands and New Britain and 9 stations in New Guinea. Upon the completion of observations in Australia and New Zealand (see p. 275), he proceeded to the Society Islands, observing at a new station on Rarotonga Island en route. After observing at C. I. W. stations Point Fareute and Papeete, Tahiti, Mr. Coleman carried out an expedition, between April 29 and June 9, on small copra-trading schooners to the Marquesas and Tuamotu Islands, occupying 2 stations in the first group and 4 stations in the second group. After again reoccupying the station Point Fareute on June 13, Mr. Coleman departed for Rarotonga Island June 14 where extensive series of diurnal-variation observations were made at 2 stations on that, island. The Director met Mr. Coleman at Rarotonga on July 15.

OBSERVATORY WORK.[1]

The achievements during the year, under this head, briefly stated, are as follows:

Watheroo Magnetic Observatory, Western Australia.—On December 1, 1921, the charge of the Observatory was transferred to Dr. G. R. Wait, and Mr. Parkinson, formerly in charge, afforded a much-needed relief. Mr. Shearer, in view of the experience gained and qualifications shown, was promoted to an observership and has served throughout the year as Dr. Wait's chief assistant. Continuous records of the numerous fluctuations in the Earth's magnetism have been obtained the entire year at this advantageously located station. Furthermore, atmospheric-electric instruments were installed during the year and arrangements were completed, during the Director's inspection visit, June 17–20, for the installations to obtain continuous photographic records of the fluctuations of the electric currents circulating in the Earth's crust, a matter of no little concern and interest in telegraphic transmission, as was pointed out in the previous year's report. Thus, before long the Watheroo Observatory will be the most completely equipped in the Southern Hemisphere for investigations relating to terrestrial magnetism, atmospheric electricity, and telluric currents. The Director reported his favorable impression of what had been accomplished by all concerned and remarked upon the general interest shown by government officials and leading men of Western Australia.

Huancayo Magnetic Observatory, Peru.—Despite unavoidable delays, such good progress was made in the constructional work that it was possible for Mr. W. F. Wallis, who has continued in charge of the observatory, to begin the photographic magnetic work on March 1, 1922. Since then continuous protographic records of the magnetic fluctuations at this high mountain station, practically on the magnetic equator, have been obtained. During the year further satisfactory progress was made with the accessory structures required for the full program of work. It is hoped that by the end of the year the first of the instruments for photographically recording changes in the electric condition of the atmosphere may also be in course of installation. Owing to the great elevation above sea of the Observatory, 11,000 feet, it is not unlikely that the atmospheric-electric fluctuations will prove of special interest, not only to students of atmospheric electricity, but also to those investigating the causes of the disturbing or "stray" effects frequently encountered in wireless transmission. Pending the completion of the experimental work at the Watheroo Observatory and at the laboratory in Washington, it has been considered best to defer, probably until 1924, installations for earth-current observations at the Huancayo Observatory. Considerable assistance has again been received from the Peruvian Government and from the American embassy. (The Director hopes in the near future to make an inspection trip to the Observatory.)

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[1] From the reports of J. A. Fleming, assistant director, and of the observers-in-charge.

Apia Observatory, Samoa.—The cooperation with the New Zealand Government at the Apia Observatory, referred to in the last Annual Report (p. 312), was maintained during the year in order to continue the atmospheric-electric and related meteorological observations, pending other arrangements. As heretofore, the New Zealand Government has kindly furnished quarters to observers of the Department, and has extended many other courtesies through its officials at Apia. A new atmospheric-electric observatory was constructed during March on the site of the old building and a small building was provided for a laboratory. The house used as a residence by the Department's representative was repaired without charge by the Public Works Department. Continuous records of the potential gradient for 85 per cent of the time were obtained, beginning April 1, with a Benndorf recording electrometer. Occasional conductivity observations were secured, and meteorological observations were taken twice a day. It is expected that during the latter part of the year potential-gradient records may be obtained with a second Benndorf recording electrometer at various positions around the grounds of the observatory simultaneously with the observations in the atmospheric-electric observatory. From November 1921 to March 1922, Dr. H. M. W. Edmonds was the Department's representative at the Observatory and thereafter Mr. Andrew Thomson, who had acquired special experience in atmospheric-electric work aboard the *Carnegie*, during her two years' cruise, 1919–1921. (See reference p. 281, regarding the Director's attendance at a special meeting of the Samoa Observatory Honorary Board of Advice, held at Wellington, July 4 and 5. Owing to uncertainty of steamer connection, it was necessary, to his regret, to abandon an intended visit to the Apia Observatory. The Director called on his excellency, the Governor of New Zealand, Lord Jellicoe, who showed no little interest in the continued welfare of the Apia Observatory.)

MacMillan Baffin Land Expedition.—As a result of the Department's cooperation with the MacMillan Baffin Land Expedition, successful observatory work was accomplished for 7½ months, beginning with November 1, 1921, at the winter quarters of the expedition in southwestern Baffin Land at Bowdoin Harbor. Continuous photographic records of magnetic declination, horizontal intensity, and vertical intensity, and of the electric potential-gradient of the atmosphere, were obtained, as also the necessary control magnetic observations and scale-value determinations. The type of temporary observatory designed by the Department proved satisfactory. Meteorological and tidal observations were likewise obtained, and 69 specimens of rock were collected in Baffin Land and Labrador for examination by the Geophysical Laboratory.

Washington, District of Columbia.—Redeterminations as necessary of instrumental constants and comparisons and standardizations of magnetic instruments before and after assignment for field use were continued in the standardizing magnetic observatory. A compass-variometer for special investigations of local magnetic anomalies and several dip-circles were calibrated for different values of intensity and inclination, varying the magnetic field as necessary by the system of Helmholtz-Gaugain coils installed in the observatory. The final standardization in intensity for the magnetometers returned by Messrs. Brown and Parkinson included comparisons with C. I. W. sine galvanometer No. 1, thus giving indirectly, through the comparison work at Teddington, England, and at Kakioka, Japan, the relations between the types of electromagnetic instruments of Great Britain, of the Magnetic Survey of Japan, and of the Carnegie Institution of Washington.

The *experimental observatory on the deck of the Laboratory* at Washington was continued in operation throughout the year, photographic records of the electric potential-gradient and of the conductivity of the atmosphere being obtained (see p. 273).

Miscellaneous.—Besides the extensive series of observatory comparisons with the adopted standards of the Department obtained by Mr. Parkinson (see p. 276), comparisons of observatory standards were obtained during the year by other observers of the Department staff at Christchurch, New Zealand; Huancayo, Peru; Melbourne, Australia, and Kakioka, Japan.

Magnetic and allied observations during the solar eclipse of September 21, 1922.—In addition to the special program of observations to be made in connection with this eclipse, which was prepared by Messrs. Bauer and Fleming and supplied to expeditions and observatories, the following final arrangements were made during the Director's visit to Australia:

(1) A detailed program of special observations pertaining to terrestrial magnetism and atmospheric electricity at the Department's magnetic observatory, Watheroo, Western Australia, this station being south of the belt of totality.

(2) Special magnetic observations, chiefly of the magnetic declination, at stations within the belt of totality, namely, at Wallal, Western Australia, by Mr. Hargreaves from England, who will be stationed at the same place where the Lick Observatory party, under the direction of Dr. Campbell, will be located; at Cordillo Downs, South Australia, by Professor Kerr Grant of the University of Adelaide, and by Mr. A. L. Kennedy, chief assistant of the Adelaide Observatory (this station will be where Professor Dodwell, government astronomer of South Australia, will be making his astronomical observations); at Coongoola, Queensland, Australia, by Observer D. G. Coleman, of the Department of Terrestrial Magnetism. It is expected that the astronomical party of Victoria under the direction of Dr. J. M. Baldwin, and that of New South Wales under the direction of Professor Cooke, will be located at Goondiwindi, Queensland, and that, time and personnel permitting, special magnetic observations will be made.

Information has been received that other institutions and observatories will arrange for special observations in accordance with our published program.

INSTRUMENT WORK AND BUILDINGS.[1]

Classification of work.—The larger part of the work done in the instrument-shop during the year was devoted to the design and construction of new instruments and apparatus. About one-quarter of the time was given to the design and development of experimental apparatus for the different divisions and sections. The remaining time was about equally divided between improvements and repairs of instruments and buildings, and miscellaneous work and stock.

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[1] From the reports of the assistant director, J. A. Fleming, and of the foreman of the instrument-shop, C. Huff.

New work.—The principal new work may be summarized as follows: (1) Completion of three standardized atmospheric-electric conductivity apparatuses for the photographic registration of both positive and negative conductivity after the designs developed last year, for use at the Department's observatories; (2) the design, preparation of drawings, and partial construction of three standardized potential-gradient apparatuses with photographic registers for observatory use; (3) partial construction of two standardized photographic registers for atmospheric-electric instruments for experimental and emergency use; (4) construction of six field galvanometers and tripods as developed and designed by the Department for use with earth inductors (these are Department Nos. 31X to 36X); (5) design, preparation of drawings, and partial construction of ten standardized string electrometers somewhat along the lines of the Wulf type. Other new work included a special compass attachment for dip circle designed and constructed for use during sledge-trips on Captain Amundsen's *Maud* Expedition; with this design sightings may be made directly on celestial bodies, so that, together with the sextant and artificial horizon for time-work, the dip circle may serve for the complete determination of the three magnetic elements. Besides other special equipment for the *Maud* Expedition, a potential-gradient apparatus for absolute observations was designed and constructed with necessary accessory equipment and reserve parts.

Experimental work.—Considerable time was given to the accurate finishing of eight rotors and to the finishing and aligning of shaft connections between rotors and motor-drive for Dr. Barnett's special investigations on magnetization by rotation. About 100 pounds of non-magnetic brass and "lumen" castings were also made for the Section of Experimental Work in Magnetism, and other miscellaneous assistance was given from time to time. A special experimental apparatus for the investigations by Mr. Peters regarding instrumental dynamic deviations on board ship was constructed, as also miscellaneous appliances for other experimental work.

Improvements and repairs of instruments.—All instrumental equipments for the field parties dispatched during the year were thoroughly overhauled, repaired, and readjusted as necessary. Because of the lack of a sufficient number of earth inductors for field use, special arrangements were made to adapt marine earth-inductors Nos. 3 and 7 for land observations. A telescope mounting was provided for earth inductor No. 3, so that this instrument might be used for rapid determinations of declination as well as of inclination.

Miscellaneous.—Seven general drawings and detail drawings were completed of the Department's design of magnetometer-inductor.

The drawings for standardized atmospheric-electric equipment and for the various observatory buildings were kept current according to the instrumental and constructional developments.

A motor-pit with concrete walls and housing was built on the east side of the Experiment Building, and a number of concrete piers and changes in piers and motor-pit as necessitated by the development of the experimental work on magnetization by rotation were made. A substantial reinforced-concrete pier for mounting of special collimating mark for the standardizing magnetic observatory was placed at a point about 280 feet north of the observatory, and the necessary mechanical work for mounting the collimating lens and its reticle was begun; the general plan for this work was developed by Mr. Johnston.

MISCELLANEOUS ACTIVITIES.

American Geophysical Union.—At the annual meeting of the Union in Washington, March 6 to 8, 1922, the following reports were presented by members of the Department:

LOUIS A. BAUER. Progress report of Committee on Relations between Terrestrial Magnetism, Terrestrial Electricity, and Solar Activity. (The members of the committee are Louis A. Bauer, chairman; C. G. Abbot, R. L. Faris, G. E. Hale, and C. F. Marvin. See abstract, p. 289.)

J. A. FLEMING. Progress report of Committee on Magnetic Standards, and Instruments and Methods for Aerial Magnetic Measurements. (Members of committee, J. A. Fleming, chairman; C. G. Abbot, J. P. Ault, S. J. Barnett, and J. T. Watkins. See abstract, p. 299.)

S. J. MAUCHLY. Progress report of Committee on Earth-Currents and Polar Lights (Members of committee, S. J. Mauchly, chairman; J. H. Dellinger, A. J. Henry, A. G. McAdie, A. G. Mayor, and W. E. Parker. See abstract, p. 305.)

Among the officers for the period July 1, 1922 to June 30, 1924, are the following members of the Department: Louis A. Bauer, chairman of the American Geophysical Union and vice-chairman of the Section of Terrestrial Magnetism and Electricity; J. P. Ault, chairman of the Section of Physical Oceanography; J. A. Fleming, secretary of Section of Terrestrial Magnetism and Electricity.

International Geodetic and Geophysical Union.—The Director of the Department attended the Rome meetings of the International Union, May 2 to 10, 1922, as a delegate from the National Research Council and the American Geophysical Union, and as secretary and director of the Central Bureau of the International Section of Terrestrial Magnetism and Electricity. Various reports were prepared for these international meetings by Messrs. Bauer, Fleming, Mauchly, and Peters. For a summary of the proceedings and chief conclusions reached at these international meetings, see pages 292–294.

The Director has continued throughout the year his duties as secretary and director of the Central Bureau of the International Section of Terrestrial Magnetism and Electricity.

National Research Council.—Various duties have been performed by Messrs. Ault, Barnett, Bauer, Fleming, Mauchly, and Peters in connection with committees of the council, or in accordance with requests for information on specific topics. Suggestions and drawings regarding the mounting of a magnetic variometer for exhibit purposes in the National Academy building were prepared by Messrs. Bauer and Fleming.

Director's inspection trip.—After the conclusion of the meetings of the International Geodetic and Geophysical Union and of International Astronomical Union at Rome, May 2–10, 1922, the Director sailed from Marseilles on May 19 for Western Australia and New Zealand. Arriving at Perth on June 15, an inspection trip was made to the Department's magnetic observatory at Watheroo, June 17 to 20, and arrangements were completed for continuous earth-current observations at this observatory (see p. 277). En route to Perth the observatories at Bombay and Colombo were visited. On July 4 and 5 the Director attended a specially called meeting at Wellington of the Samoa Observatory Honorary Board of Advice, at which matters were discussed relating to the continued operation of the Apia Observatory under the joint auspices of New Zealand, the British Admiralty, and the Carnegie Institution of Washington. Arrangements were also made for special magnetic and electric observations at various stations in Australia during the solar eclipse of September 21, 1922, by members of the Department and other expeditions. At Perth and Wellington lectures were given on the Earth's magnetism and electricity before representative scientific societies, as well as talks before students of physics on problems of research in these subjects. While homeward bound from New Zealand, the Director met Observer D. G. Coleman at Rarotonga, and conferred with him with regard to the continuation of the field work which he is successfully carrying out on islands of the Pacific Ocean and in New Zealand and Australia.

Library Work.—The number of books and pamphlets received during the year from all sources was over 800, making now the total number of accessioned publications in the library of the Department nearly 12,000. Mr. Harradon, as librarian-translator, has, furthermore, made a large number of translations for various purposes, and, with the assistance of Miss Noll, has done considerable bibliographical work.

PERSONNEL AND DUTIES.

Director: Louis A. Bauer.

Assistant Director: J. A. Fleming.

Division of Investigational Work (under the Director's charge):

Section of Terrestrial Magnetism and Electricity: Louis A. Bauer, in charge; W. J. Peters, chief assistant; O. H. Gish, associate physicist; C. R. Duvall, expert computer; C. C. Ennis, computer-draftsman; H. D. Harradon, librarian-translator; Emma L. Tibbetts, stenographer-computer; and Hazel Noll, computer and library assistant, since February 1.

Section of Experimental Work in Magnetism: S. J. Barnett, chief; C. A. Kotterman, laboratory assistant and photographer; and assistance from shop and building personnel. (Mrs. L. J. H. Barnett acted as voluntary assistant to Dr. Barnett.)

Section of Experimental Work in Terrestrial Electricity: S. J. Mauchly, chief; C. M. Little, assistant observer and stenographer, November 1 to March 20; Mary C. Parker, computer and stenographer since February 23. (Temporary assignments: O. H. Gish, associate physicist, from January 9; C. C. Ennis, computer-draftsman, from April 17.)

Division of Observational and Administrative Work (under the Assistant Director's charge):

Administrative Work: J. A. Fleming, in charge; M. B. Smith, chief clerk, J. J. Capello, property clerk and stenographer; and A. J. S. Dixon, clerk.

Observatory Work: J. A. Fleming, in charge; W. F. Wallis, observer-in-charge, Huancayo Magnetic Observatory, Peru; C. M. Little, assistant observer at Huancayo since March 21; G. R. Wait, observer-in-charge, and J. Shearer, observer, Watheroo Magnetic Observatory, Western Australia; observer-in-charge of atmospheric-electric work at Apia Observatory, H. M. W. Edmonds from November to March, thereafter, Andrew Thomson; and W. C. Parkinson, in charge of observatory comparisons. (Since return to Washington, Dr. Edmonds has been engaged on the reduction of observatory observations.)

Section of Ocean Work: J. P. Ault, chief; H. F. Johnston, magnetician; C. R. Duvall, expert computer, occasional assistance; A. Erickson, first watch-officer, caretaker of the *Carnegie* while out of commission.

Section of Land Magnetic Survey: H. W. Fisk, chief; H. U. Sverdrup, associate magnetician, November to March; C. R. Duvall, expert computer, since April 11. Occasional office assignments: Observers H. R. Grummann, J. T. Howard, and W. A. Love, and Emma L. Tibbets, computer. Occasional field assignments: Observers F. Brown, D. G. Coleman, P. H. Dike, R. H. Goddard, J. W. Green, H. R. Grummann, J. T. Howard, and W. C. Parkinson.

Instrument Work and Buildings: J. A. Fleming, in charge; C. Huff, foreman of instrument-shop; G. H. Jung and W. F. Steiner, instrument-makers; A. Smith, carpenter; J. G. Lorz, mechanician; W. T. Butt, apprentice; S. W. Malvin, gardener and caretaker; and P. E. Brooke, night-watchman. (E. A. Tibbals, temporary instrument-maker, since February 6.)

ABSTRACTS OF PUBLICATIONS AND INVESTIGATIONS.

Preliminary results of ocean magnetic observations on the *Carnegie* from Apia to Balboa and Washington, July to November, 1921. J. P. Ault, Terr. Mag., vol. 26, 121–128 (December 1921).

This paper completes the series of papers giving the preliminary results of the magnetic observations on the *Carnegie* during her recent world cruise (No. VI), which began at Washington, on October 9, 1919, and ended at Washington, November 10, 1921. Notes on the passages from Apia to Balboa and from Balboa to Washington are given; in addition to the general details of the passages, they include pertinent remarks regarding auxiliary observations, determination of ocean currents, and a description of the "swinging-ship" operations in Chesapeake Bay on November 7, 1921. The results of these swings showed once more the absence of any appreciable magnetic deviations at the positions where the various magnetic instruments are mounted aboard the *Carnegie*.

Preliminary average annual changes of the magnetic elements in the Pacific and Atlantic oceans, 1906 to 1921. J. P. Ault.

TABLE 2.—*Preliminary average annual changes of the magnetic elements in the Pacific and Atlantic Oceans.*

Latitude.	Long. east of Gr.	Approximate dates showing time-intervals.	Average annual changes.			No. of values utilized.	Annual change in declination.			
							Chart values.		Chart corrections.	
			D	I	H[a]		U. S.	B. A.	U. S.	B. A.
°	°		′	′			′	′	′	′
35.9 N	285.1	1918.5–1921.8	......	1 N	−1	4 and 4	......	......	......	......
35.3 N	285.3	1918.5–1921.8	4 W	......	......	8 and 7	4 W	4 W	0	0
12.2 N	282.7	1915.3–1921.8	......	4 N	+1	3 and 3	......	......	......	......
12.0 N	282.6	1915.3–1921.8	2 E	......	......	3 and 5	2 W	0	4 E	2 E
5.6 N	281.1	1918.4–1921.8	5 E	......	......	5 and 5	0	1 E	5 E	4 E
5.3 N	281.1	1918.4–1921.8	......	6 N	+4	3 and 3	......	......	......	......
2.7 N	274.9	1915.4–1921.8	......	8 N	+3	6 and 6	......	......	......	......
2.6 N	275.4	1915.4–1921.8	4 E	......	......	11 and 11	1 E	2 E	3 E	2 E
5.9 S	260.2	1908.3–1921.7	6 E	......	......	2 and 3	2 E	2 E	4 E	4 E
6.2 S	260.7	1908.3–1921.7	......	4 N	−1	2 and 2	......	......	......	......
13.4 S	192.9	1906.3–1921.5	3 E	......	......	3 and 4	2 E	2 E	1 E	1 E
13.4 S	192.8	1906.3–1921.5	......	4 S	−3	3 and 2	......	......	......	......
14.0 S	189.0	1916.5–1921.6	1 E	......	......	3 and 4	2 E	1 E	1 W	0
14.3 S	188.7	1906.7–1921.6	......	3 S	−1	3 and 1	......	......	......	......
17.7 S	188.7	1916.4–1921.6	4 E	......	......	3 and 7	2 E	1 E	2 E	3 E
17.8 S	188.8	1916.4–1921.6	......	1 S	+1	3 and 4	......	......	......	......
24.5 S	201.6	1912.8–1921.6	3 E	......	......	1 and 4	3 E	3 E	0	0
24.6 S	201.9	1912.8–1921.6	......	1 S	−1	2 and 2	......	......	......	......
27.9 S	189.9	1916.4–1921.6	4 E	......	......	4 and 3	3 E	2 E	1 E	2 E
28.3 S	190.0	1916.4–1921.6	......	0	−2	3 and 2	......	......	......	......
29.9 S	217.9	1912.5–1921.6	3 E	......	......	2 and 2	4 E	4 E	1 W	1 W
29.9 S	218.6	1912.5–1921.6	......	1 N	−1	1 and 1	......	......	......	......
30.2 S	258.6	1913.0–1921.7	4 E	......	......	3 and 4	1 E	1 E	3 E	3 E
30.5 S	258.3	1913.1–1921.7	......	5 N	−2	2 and 2	......	......	......	......
31.1 S	240.9	1912.6–1917.0	3 E	......	......	4 and 4	2 E	3 E	1 E	0
31.1 S	240.9	1917.0–1921.7	5 E	......	......	4 and 5	2 E	3 E	3 E	2 E
30.9 S	241.0	1912.6–1917.0	......	3 N	+1	2 and 3	......	......	......	......
30.9 S	241.0	1917.0–1921.7	......	3 N	+1	3 and 3	......	......	......	......
31.2 S	192.0	1912.5–1921.6	3 E	......	......	1 and 2	3 E	2 E	0	1 E
31.3 S	192.7	1912.5–1921.6	......	0	+1	1 and 1	......	......	......	......
31.2 S	250.7	1917.0–1921.7	......	3 S	−1	3 and 2	......	......	......	......
29.7 S	224.6	1912.5–1921.6	......	4 N	0	1 and 1	......	......	......	......
31.9 S	235.4	1912.6–1921.7	4 E	......	......	1 and 2	3 E	3 E	1 E	1 E
31.8 S	234.6	1912.6–1921.7	......	1 N	0	2 and 3	......	......	......	......
32.0 S	246.0	1917.0–1921.7	......	3 S	−2	1 and 1	......	......	......	......

[a] Units of the fourth decimal C. G. S.

The average annual changes in the values of the magnetic elements, given in table 2, were obtained by using the results of observations made on the *Carnegie* and *Galilee* in the vicinity of the intersections of their various tracks. The method employed in computing the tables is the same as that used in discussing average annual changes for the southern Atlantic.[1] The charts referred to are U. S. H. O. No. 2406 for 1920, and B. A. No. 3777 for 1917.

Terrestrial magnetism. J. P. Ault. North American Almanac for 1923, 64–73.

This article was prepared at the request of the North American Almanac Company, on the general subject of terrestrial magnetism. It includes a brief history of the beginnings and development of the science of terrestrial magnetism, and briefly discusses some of the theories which attempt to explain the origin and manifestations of the Earth's magnetic phenomena. A short description of the *Carnegie* and her cruises, and of the land work of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington, is also given.

The *Carnegie* and her cruises, with special reference to Cruise VI. J. P. Ault.

This illustrated lecture, giving a general and somewhat popularized account of the work of the *Carnegie*, was presented on the following occasions: Washington Arts Club, December 15, 1921; Association of American Geographers at the December meeting in Washington; Men's Club of Foundry M. E. Church of Washington, February 17, 1922; College Women's Club of Washington, April 12, 1922; Washington Society of Engineers, October 18, 1922.

Rotation by magnetization. S. J. Barnett.

Since the report of 1921 a great deal of progress has been made in improving the apparatus and in determining and reducing the corrections. Three extra coil-systems have been installed to compensate the residual parts of the Earth's field not annulled by the main compensating system, and three variometers have been installed to control them. This and a more nearly symmetrical arrangement of the magnetometer have made it possible to reduce uncertainty as to eddy-current effects. The rotor journals and bearings have been improved, and the rotors have been balanced as far as practicable. Improvements in the driving mechanism have been made, and the motor corrections have been more thoroughly studied. The process of demagnetization of the rotors has been greatly improved, making the elimination of several extraneous effects less difficult, and other improvements have been made. A long-suspected systematic error in the 1917 magnetometer observations, causing the results to differ considerably from those obtained by the method of electromagnetic induction in 1914 and 1915, has been found. All methods now agree. Rotating any ferromagnetic substance investigated at one revolution per second is equivalent to placing it in an axial magnetic field with intensity -3.55×10^{-7} gauss, within about 1 part in 10. This result would be expected if a single type of negative magneton, with ratio of angular momentum to magnetic moment equal to m/e, one-half that of a ring of electrons, were responsible for ferromagnetism. Abraham showed in 1903 that a superficially charged Lorentz electron in rotation has the moment and the momentum giving this ratio. If a ring of electrons is chiefly responsible for ferromagnetism, positive magnetons also participate, as stated before.

An account of the work up to April 1922 was presented to the American Physical Society at the Washington meeting by S. J. and L. J. H. Barnett. (See Phys. Rev., vol. 20, pp. 90–91, July 1922.)

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[1] See Annual Report of the Director of the Department of Terrestrial Magnetism, Year Book of the Carnegie Institution of Washington for the year 1920, pp. 310–312.

The angular momentum of the elementary magnet. S. J. Barnett. Bull. National Research Council, vol. 3, 235–250 (August 1922).

This is a general treatment of the rôle of angular momentum in magnetism. It describes briefly Maxwell's attempt to detect by direct experiment any angular momentum of electricity flowing in a coil of wire, or any angular momentum associated with the Ampèrian currents in magentized iron; the experiments of S. J. and L. J. H. Barnett on the magnetization of ferromagnetic substances by rotation, first successful with iron in 1914 (nearly a quarter of a century after an attempt by John Perry) and since extended to other ferromagnetic materials; the attempt of Richardson in 1907 to rotate iron by magnetizing it, and the later and successful experiments in this field from 1915 to 1919 by Einstein and de Hass, together and separately, on iron, by J. Q. Stewart and by E. Beck on iron and nickel, and by G. Arvidsson on iron. The paper also gives the general theory of all these experiments, and discusses the bearing of the experimental results on the theory of the magneton or elementary magnet. In the theory of magnetization by rotation special attention is devoted to the cases of elastic magnetization and completely inelastic magnetization.

Note on the formula for the electric polarization of an insulator moving in a magnetic field. S. J. Barnett.

From the fundamental equations of electromagnetic theory as developed by Cohn and by Minkowski, a general expression has been obtained for the polarization produced in an insulator by its motion in a magnetic field. If K denotes the dielectric constant of the medium, μ its permeability, I its intensity of magnetization, B the magnetic induction, and v the velocity, the formula for the polarization, in the approximate form obtained by Abraham, is

$$P=\frac{K}{4\pi c}\left(1-\frac{1}{\mu K}\right)[vB]$$

This polarization consists of two distinct parts; one, P_1, produced by the motional intensity $\frac{1}{c}[vB]$ acting on the moving part of the insulator; the other, P_2, due to the motion of the magnetons.

On the theory of Lorentz and Larmor, the ether is at rest, so that only the electrical fraction $(K-1)/K$ of the insulator is in motion. Hence.

$$P_1=\frac{K-1}{4\pi}\,\frac{1}{c}\,[vB]$$

This result has been fully confirmed by experiments made on air in 1901 by Blondlot, on ebonite in 1904 by H. A. Wilson, and on rosin, sulphur, and ebonite in the interval 1902–1908 by myself.

The polarization P_2 is given by the expression

$$P_2=\frac{1}{c}\,[vI]=\frac{1}{4\pi c}\,\left(1-\frac{1}{\mu}\right)\,[vB]$$

This follows from a simple theorem of Maxwell's: The motion with velocity v of an electromagnetic system with vector potential A produces an electric field the potential of whose polar part is $\varphi=\frac{1}{c}\,(Av)$. An immediate consequence of this is that the electric moment of the distribution produced by the motion is equal to $\frac{1}{c}\,[vm]$, where m is the magnetic moment. Applying this to the unit volume, we obtain the above expression for P_2.

Adding together the expressions for P_1 and P_2, we obtain the expression for P given above as hitherto derived only on the basis of the Cohn-Minkowski equations.

This result, like Maxwell's theorem, is correct to quantities of the first order in $\frac{v}{c}$. Reference is made to results obtained by Budde, Lorentz, and others, which are implicit, to quantities of the first order in $\frac{v}{c}$, in Maxwell's theorem, the approximate character of which is due to its being based on a principle of relativity assuming equality of electromotive intensity and magnetic induction to fixed and moving observers.

The permeability μ differs from unity so slightly for all insulators that it is impossible at present to distinguish experimentally between P and P_1. By embedding a large number of small steel spheres in wax, however, M. Wilson and H. A. Wilson (Roy. Soc. Proc. A, 89, 1914, p. 99) formed a composite dielectric whose mean permeability, for large volumes, was much greater than unity. On the assumption that this procedure is justifiable, the results of experiments which they made on the electric effect of moving the composite substance in a magnetic field support the above equation for P. M. and H. A. Wilson concluded that their results therefore supported the (Einstein-Minkowski) principle of relativity. As shown above, however, the result is entirely independent of this special theory, and follows from Maxwell's theorem based on a much older, though less exact, relativity principle.

[An abstract of the paper as presented at the American Physical Society meeting in April 1922 will be found in Phys. Rev., vol. 20, 114 (July 1922).]

Electric fields due to the motion of constant electromagnetic systems. S. J. Barnett.

Maxwell's equation for the electromotive intensity and a theorem derived from it in §600 of his Treatise are applied to the investigation of a number of simple but fundamental fields due to the motion of constant electromagnetic systems. According to Maxwell's theorem, the motion produces an electric field whose polar part is derivable from the potential $\varphi = \frac{1}{c}(Av)$, where A is the vector potential of the system, v its velocity, and c the velocity of light. If σ denotes the electric density produced by the motion at any part of the system where the current density is i, and if Q denotes the total electric moment produced, while M denotes the magnetic moment of the system, it follows immediately from Maxwell's theorem that $\sigma = \frac{(iv)}{c^2}$ and $Q = \frac{1}{c}[vM]$. The three equations are correct to the first order in $\frac{v}{c}$. The second result was obtained from Clausius's theory in 1880 by E. Budde; the corresponding result with the correction for the second order term in $\frac{v}{c}$ was obtained by Lorentz in 1895, and by Silberstein from Minkowski's equations in 1914. The third was recently given for a special case, but with the wrong sign, by Swann. For a constant (originally) unelectrified system, if B denotes the magnetic induction, and E the electromotive intensity, $\frac{\partial A}{\partial t} = -(v\nabla)A$, and $E = \frac{1}{c}(v\nabla)A - \frac{1}{c}\nabla(Av) = \frac{1}{c}[Bv]$. A number of special cases are considered.

I. *Two parallel wires with currents* $\pm I$, v being parallel to I. Here $\frac{\partial A}{\partial t} = 0$ and $E = -\frac{1}{c}\nabla(Av)$. The motion produces charges $\pm q = \pm\frac{Iv}{c^2}$ per unit length along the wires.

II. *Two plane parallel sheets* with currents $\pm I$ per unit length, v being parallel to the stream-lines. Between the sheets the electric field is uniform and normal to v, the charges per unit area being $\pm q = \pm \frac{Iv}{c^2}$. Again $E = -\frac{1}{c}\nabla(Av)$.

III. An infinite uniform circular cylindrical current sheet, with magnetic moment M per unit length, and v normal to the axis. $\frac{1}{c}(Av)$ is such as to produce a uniform field with intensity $\frac{1}{2c}[Bv]$ within the cylinder, and without the cylinder the field of an axial electric line doublet with moment $\frac{1}{c}[vM]$ per unit length. $\frac{1}{c}(v\nabla)A$ doubles the intensity inside and cancels it outside.

IV. *A spherical current sheet* with magnetic moment M and current I per unit length of the diameter, v being normal to the magnetic axis. Inside $\frac{1}{c}(Av)$ gives a uniform intensity $-\frac{1}{c}\nabla(Av) = \frac{1}{2c}[Bv]$; outside, the field of a central electric point doublet with moment $\frac{1}{c}[vM]$. $\frac{1}{c}(v\nabla)A$ alters the intensity to $\frac{1}{c}[Bv]$ everywhere.

V. *Two cylindrical coaxial magnetic poles with a radial field between them,* v being parallel to the axis. Here $\frac{1}{c}(Av) = 0$, there are no charges, and $E = \frac{1}{c}(v\nabla)A = \frac{1}{c}[Bv]$.

VI. *A conducting cylinder or sphere with uniform intensity of magnetization I in motion normal to the magnetic axis.*—All the formulæ, for points outside the system, are exactly similar to those for the cylindrical and spherical current sheet, but I has now the meaning attached to it here instead of that above. Within the material of the system, the electromotive intensity is zero. The sphere or cylinder is electrically polarized, with polarization, or electric moment per unit volume, given by $\frac{1}{c}[vI]$. The field of this polarization gives the polar part of the external field, and, together with the internal part of the solenoidal field, just balances the motional intensity $\frac{1}{c}[vB]$ inside the system; or we may consider that the effect of the polarization is neutralized by that of an equal and opposite polarization due to the charges induced in the parts of the conductor adjacent to the individual magnetons, and that the distribution produced by the motional intensity gives the polar part of the external field and also the polar part of the internal field, which, together with the solenoidal part, just balances the motional intensity.

VII. *Two similar infinitely long magnets with rectangular cross-sections* placed parallel with opposite poles facing one another symmetrically and in motion parallel to their lengths and normal to the lines of induction of the magnetic field. The vector potential is zero over the central plane parallel to the motion and normal to the pole faces. It is everywhere parallel to the velocity. Its magnitude is independent of the coordinate parallel to the length. Thus $\frac{\partial A}{\partial t} = -(v\nabla)A = 0$, and the total intensity outside the substance of the magnets, viz, $E = -\frac{1}{c}\nabla(Av) = \frac{1}{c}[Bv]$ is polar and lies in planes normal to the motion, or is two-dimensional, like the magnetic field. Within the magnets themselves the total electromotive intensity is zero and there is an electric polarization $\frac{1}{c}[vI]$ at points where the intensity of magnetization is I. It is immaterial whether the intensity is calculated from $[Bv]$, or whether it is calculated from $-\nabla(Av)$; or we may consider that the effect of the polarization is exactly neutralized by that of the equal and opposite polarization due to the charges induced on the parts of the conductor adjacent to the individual magnetons, and that the net electric field remaining is due to the electric displacement produced by the motional intensity $\frac{1}{c}[vB]$. In connection with this case, approximately realized in one of my experiments, Swann has stated that Maxwell's equation for the electromotive intensity can not be immediately applied to the case of rectilinear motion to show that the field is polar, *because in this case the vector potential is not independent of the time.* This is clearly an error. Several examples of the contrary are given above in addition to this particular case.

VIII. *A conducting solid of revolution magnetized along its axis* (either permanently or inductively or both) *and in steady rotation about this axis.*—Jochmann in 1863 and Larmor in 1884, referring to Jochmann, gave the general form of the solution and worked out all the details for the case in which the solid is a sphere. Recently Swann, who does not refer to the earlier work, has again given most of the details for the sphere. The field is a purely polar field arising from the superposition of various parts which are discussed in detail. Maxwell's theorem can not be applied directly to the complete rotating system, but it can be applied to each element, which has its own linear velocity and vector potential.

Some remarks on electromagnetic induction. S. J. Barnett.

This paper is devoted chiefly to historical and critical comments on matters connected with experiments previously made by the author in the field of electromagnetic induction.

Experiments on the motion of insulators in magnetic fields by Faraday, Blondlot, H. A. Wilson, H. A. and M. Wilson, and the author are referred to and the general theory is given in detail. H. A. Wilson considered his experiments to prove that the motional electric *intensity* or *electromotive force* is proportional to $(K-1)$, which is not correct. According to all theories the motional intensity is independent of the medium and equal to $\frac{1}{c}[vB]$, while on the theory of Larmor and Lorentz the resulting *polarization* is proportional to $(K-1)$, the result supported by all the experiments.

Wilson's procedure is as follows: He begins with the (erroneous) assumption that the Larmor-Lorentz theory requires that the *electromotive force* $[F']$ in an insulator "should be equal to the electromotive force $[F]$ in a conductor multiplied by the factor $(1-K^{-1})$, where K is the specific inductive capacity." But when he comes to formulate his equations, he makes the electromotive force F, *not* F', as required by his assumption, act on the moving part of the insulator. Then, going back to his fundamental assumption, he *calls* the quantity $(1-K^{-1})\,F$, proportional to the effect observed, the electromotive force, while this is really F, and hence draws the conclusion: "The amount of the displacement agrees with that calculated on the assumption that an electromotive force is induced in the dielectric equal to that in a conductor multiplied by $(1-K^{-1})$." The correct conclusion is: On the assumption that the motional intensity or electromotive force is the same in all insulators and conductors, as required by all theories, the experiment proves that only the electrical fraction $(1-K^{-1})$ of the dielectric is moving.

The theory of Hertz is shown to be inconsistent with Maxwell's theory in that it requires, in general, a surface divergence or a volume divergence of the electric displacement when the motion occurs.

Reference is made to a paper by Swann in which the author's experiments on electromagnetic induction in the case of rotary motion are included among those made to solve the so-called problem of unipolar induction. This is not correct. Indeed, several pages of the original paper were devoted to an attempt (not free from error) to prove that such experiments could not be used for that purpose. The experimental results, as stated in the paper, are consistent with current theory (that of Maxwell and Lorentz). As to the electrical field in unipolar induction, when a conducting solid of revolution magnetized along its axis is in steady rotation about this axis, it was worked out long ago by Jochmann and later by Larmor, who have given all the details for the case of the sphere. The formulæ given by Swann are not new, but so far as they go are identical with those of the early investigators. The considerations which Swann has given to show that, on the basis of the electron theory, when a solenoid or an Ampèrian whirl rotates on its axis, the lines of induction can not be considered to share the rotary motion, were given by Pegram in 1917, together with the theory, also given by Swann, of the author's and other experiments on the basis of Maxwell's equation for the electromotive intensity. The theorem used by Swann to investigate the molecular field is also not new, having been given by Maxwell.

The author's experiments on electromagnetic induction and translatory motion are briefly described and his earlier and later interpretations of one of them are referred to. The latter, whose final acceptance was hastened by a letter from Professor Eddington, is fundamentally identical with an interpretation published much later by Swann. Swann gives the mathematical theory by a process unnecessarily complicated, stating that Maxwell's equation for the electromotive intensity can not be immediately applied to show that the field is polar, *because the vector potential is not independent of the time*, which is incorrect. In this paper the theory for both a steady two-dimensional field and for the actual case of the experiments is given according to Maxwell's equation.

The results of the experiments on rotary and translatory motion are compared.

Progress Report of Committee on Relations between Terrestrial Magnetism, Terrestrial Electricity, and Solar Activity.[1] Louis A. Bauer.

As the result of a preliminary meeting of the Committee on March 4, 1922, at Washington and by correspondence, the following progress report of the Committee on Relations between Terrestrial Magnetism, Terrestrial Electricity, and Solar Activity, was made.

Mr. Bauer stated that various measures of solar activity have been computed at the Department of Terrestrial Magnetism, as based on the following data: Wolf-Wolfer sun-spot numbers, Greenwich sun-spot areas, Greenwich faculæ areas, flocculi areas, solar prominences according to the observations at various observatories, especially at Kodaikanal, India, and solar-constant values obtained by the Smithsonian Institution. The director of the Kodaikanal observatory, Mr. John Evershed, courteously supplied the Department of Terrestrial Magnetism with the various publications by the observatory, as well as recent data in manuscript. In his letter of October 10, 1921, he stated that "he hoped by cooperation with some American observatories to get data for practically every day in the year." It will thus become ultimately possible to obtain from solar-prominence observations desired data for supplementing the measure of solar activity derived by Mr. Bauer from the sun-spot numbers, which measure, it will be recalled, was found more useful, in general, than the sun-spot numbers direct, for disclosing relationship between solar activity and magnetic and electric phenomena. Mr. Bauer also reported having received a letter from Professor Wolfer, kindly offering to supply regularly, in advance of publication, the sun-spot tables to the Department of Terrestrial Magnetism. Professor Wolfer has expressed a favorable opinion as to the suitability for short-interval comparisons of the D-measure (average departure) of solar activity, used in Mr. Bauer's investigations.

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[1] Presented at the annual meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, March 7, 1922. Members of Committee: Louis A. Bauer, chairman; C. G. Abbot, R. L. Faris, G. E. Hale, and C. F. Marvin.

In view of the fact that the Department of Terrestrial Magnetism is planning to install earth-current lines at its magnetic observatories, a discussion of the existing earth-current observations was undertaken. From the series of earth-current observations, 1910–1920, made at the Observatorio del Ebro, Tortosa, Spain, interesting relations have been found between earth-currents, terrestrial magnetism and electricity, and solar activity. (See abstract, pp. 290–291.)

In connection with the investigations as briefly outlined, it has been found desirable to obtain some meteorological quantity also which could be utilized in the study of relations between certain meteorological and other geophysical phenomena, and solar activity. Mr. Bauer is at present trying out for this purpose the "time barometric gradient" (differences of pressure, divided by the elapsed time-interval) as obtained from the recorded pressures at various stations.

Mr. Marvin reported as to how the space barometric gradients might be used in attempts to find relationship between meteorology and solar activity, and submitted a subreport on the subject.

Mr. Abbot reported upon the solar-constant observations now in progress under the auspices of the Smithsonian Institution.

Some results of recent earth-current observations and relations with solar activity, terrestrial magnetism, and atmospheric electricity.[1] Louis A. Bauer, Terr. Mag., vol. 27, 1–30 (March–June 1922).

The Department of Terrestrial Magnetism is planning to install earth-current lines for systematic observations at its magnetic observatories. This year such lines are to be installed at the Watheroo Observatory, Western Australia, and later at the Huancayo Observatory, Peru.

Various initial investigations concerning best methods of earth-current measurements have been in progress at the Department's laboratory. To Mr. O. H. Gish, appointed January 1, 1922, Associate Physicist of the Department, has been assigned the continuation of these investigations. Furthermore, in order to take advantage of the previous experience gained in such work, and to ascertain the direction in which further study is desirable, a discussion of the available data, especially for the 11-year series at the Observatorio del Ebro, was undertaken by the writer. Assistance was received from Messrs. Duvall, Ennis, and Peters, and from Miss Tibbetts.

For the first time comparisons could be made between the phenomena of terrestrial magnetism, earth-currents, and atmospheric electricity, as observed at the same station. Accordingly it has been possible not only to confirm and extend certain results previously reached by others, but also to draw important new conclusions.

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[1] Presented before the Philosophical Society of Washington, February 25, 1922.

It is hoped that the present investigation, which had to be confined to a discussion of the observational data on magnetically-calm, or on electrically-calm days, may be supplemented later by a discussion of earth-current data on disturbed days.

The chief conclusions may be stated as follows:

(*a*) The resultant horizontal earth-currents, as observed at the Ebro Observatory, flow, on the average for the year, in the direction from about 29° west of north to 29° east of south, or, approximately, in the direction from the Magnetic North Pole towards south-southeast. The average value, for the magnetically-calm days during 1914–1918, of the potential gradient of the component of the current flowing from true north to south was 0.20 volt per kilometer, and that of the component towards geographic east was 0.11 volt per kilometer, or about one-half of the north-south component. The resultant horizontal potential-gradient was 0.23 volt per kilometer, which during electric or magnetic storms may reach a value 0.8 to 1.0 volt per kilometer.

(*b*) The annual variations of the earth-current potential-gradients and of the components of the Earth's magnetism, as observed at the Ebro Observatory, may be related to one another as cause and effect only to a very minor extent; both sets of variations may have to be referred, more or less, to common causes. The range of the annual variation of the north-south electric component is about 2.5 times that of the west-east component.

(*c*) The diurnal variation of earth-currents as observed at the Ebro Observatory along lines somewhat over 1 km. long is remarkably similar to that observed at Berlin along telegraph lines, 120 and 262 km. in length, from 1884–1887. In both cases the diurnal variations for the component of the current along the meridian is considerably more pronounced (2 to 3 times) than that along the parallel of latitude. The diurnal variation in the north component of the Earth's magnetism is not such as to correspond to the direct magnetic effect of the diurnal variation of the west-east component of the earth-currents. A similar conclusion had to be reached with regard to the east component of the Earth's magnetism and the north-south component of the earth-currents. The general conclusion was that the north-south earth-current might be the result of electromagnetic induction, caused by the fluctuation during the day of the west-east component of the Earth's magnetism. If it be recalled that all analyses of the diurnal variation field of the Earth's magnetism have shown that the magnetic diurnal variation is in part to be ascribed to electric currents circulating in the regions overhead and in part to currents circulating within the Earth's crust, exact agreements between magnetic variations and earth-current variations are not to be expected. It further remains to point out that until we have some knowledge of the actual course or distribution of the earth-currents in the Earth's crust and as to how the conductivity of the crust may vary with temperature and other meteorological causes during the day and at the actual place of observation, attempts to find a quantitative relationship between terrestrial-magnetic and earth-electric effects may be futile.

(*d*) The horizontal vector-diagrams both for the magnetic and earth-electric components vary during the sun-spot cycle in about the same proportion. The earth-current vector-diagram is symmetrical about a line approximately in the direction of the Magnetic North Pole.

(*e*) The extreme diurnal range of the Ebro earth-currents reaches its highest values near the equinoctial months, and lowest near the solstitial months. Earth-currents, atmospheric electricity, the aurora borealis, and the Earth's magnetic disturbances all show similar annual variations in the ranges of their fluctuations.

(*f*) The potential gradients of earth-currents and of atmospheric electricity apparently vary during the sun-spot cycle, the former decreasing in the direction of normal flow of current, and the latter increasing with increased sun-spot activity. The diurnal ranges of the potential gradients of earth-currents, as well as of atmospheric electricity, just as is the case for the diurnal variation of terrestrial magnetism, increase with increased sun-spot activity.

(*g*) There is evidence of a similar six-hour wave in atmospheric electricity, earth-currents, and terrestrial magnetism.

Note on a simple measure of the Earth's daily magnetic activity. Louis A. Bauer, Terr. Mag., vol. 27, 31–34 (March–June 1922).

In a timely paper[1] for the Rome meeting of the International Section of Terrestrial Magnetism and Electricity, Dr. G. van Dijk, of the De Bilt Observatory, made a very desirable comparison, chiefly for the year 1915, of measures of terrestrial magnetic activity proposed by various investigators. Dr. van Dijk's paper is briefly reviewed, and, with the aid of his figures, a graphical comparison is made of the measures of magnetic activity proposed by Bidlingmaier, Chree, Schmidt, Bauer, and van Dijk.

The limitations of the computing personnel at most of the magnetic observatories require that a measure of magnetic activity be used, preferably of the linear type, which can be readily computed and which will be found to be approximately the same at stations in moderate magnetic latitudes all over the Earth. Studies are in progress to see how satisfactorily measures already used by the writer will fulfill the conditions (see last year's report (1921), p. 349).

Rome meeting of the International Section of Terrestrial Magnetism and Electricity, May 1922. Louis A. Bauer. Terr. Mag., vol. 27, 89–101 (September 1922).

A well-attended meeting of the Section of Terrestrial Magnetism and Electricity of the International Geodetic and Geophysical Union was held at Rome from May 4 to 9, 1922. Representatives from Australia, Belgium, France, Great Britain, Italy, Japan, Norway, Poland, Spain, Sweden, and the United States were present at various sessions. Besides discussion of the Agenda, which contained leading questions pertaining to terrestrial magnetism and electricity, reports were presented by national and other committees and by leading investigators.

Professor Tanakadate (Japan) tendered his resignation as president of the section because of his inability to attend to the duties involved. Dr. Charles Chree (Great Britain) was then chosen president and Professor Luigi Palazzo (Italy) vice-president. According to the statutes, the secretary and director of the central bureau, Dr. Louis A. Bauer, continues in office until the next meeting, which will be held at Madrid, Spain, in 1924. Directors J. Jaumotte (Belgium), Ch. Maurain (France), and Professor A. Tanakadate (Japan) were elected additional members of the executive committee. It was agreed that administrative matters should be left to the officers of the section.

Five committees were appointed: (1) Committee on Magnetic Surveys and International Comparisons of Instruments (Louis A. Bauer, chairman); (2) Committee on Observational Work in Atmospheric Electricity to report on Objects, Instruments, and Methods (G. C. Simpson, chairman); (3) Committee on Measures of Magnetic Characterization of Days; (4) Committee on Best Methods, Instruments, and Compilations for Polar-Light Observations; (5) Committee to Consider and Report on Best Methods and Instruments for Earth-Current Observations (Sir Arthur Schuster, chairman). The appointment of chairmen of committees 3 and 4 was deferred, pending the early entrance into the union of additional countries.

The representatives of the American Geophysical Union on these international committees are: Louis A. Bauer and N. H. Heck (No. 1); W. F. G. Swann (No.2); R. L. Faris (No. 3); J. A. Fleming (No. 4); and S. J. Mauchly (secretary of No. 5).

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[1] Activity of the Earth's magnetism and magnetic characterization of days, Ned. Med. Inst. No. 102, Utrecht, 1922.

The results of the meeting are embodied in the form of 20 resolutions, viz:

1. In view of the importance of securing world-wide cooperation in terrestrial magnetism and electricity, and remembering the great contributions in these fields by scientists and instrument-makers of countries not yet adherent to the section, hope is expressed that a day will come when collaboration of all countries in the labors of the section will be possible.

2. That the attention of directors of observatories be called to the importance of assuring themselves that the methods they employ for scale-value determinations of magnetographs are satisfactory, and that a general statement as to the methods be given in all observatory publications.

3. That in view of the diverse types of instruments in use, and diverse circumstances prevailing at the various stations, it is not advisable at present to recommend the adoption of any particular method of scale-value determination for magnetographs, nor any particular scale-value, nor to specify an opinion as to the best elements to record.

4. That national committees be requested to designate, if possible, one observatory in their respective countries for international intercomparisons of magnetic instruments, and to secure intercomparisons of magnetic instruments within their own countries at least once within the course of three years.

5. That the Committee on Magnetic Surveys and Intercomparisons of Magnetic Instruments formulate a definite scheme for securing intercomparisons of magnetic instruments between countries, and especially contiguous countries.

6. That the following are the localities at which additional magnetic observatories are most desirable: Northeast Canada, Northeast Siberia, Bermuda, St. Helena (or French West Africa), Italian North Africa, British South Africa, and Northeast Australia.

7. That the steps already taken by the New Zealand Government regarding the continuation of the Apia Observatory, in Samoa, are highly commended, and it is hoped that the New Zealand Government may find it possible to provide for the continued full activities of the Observatory.

8. That the continuation by the Argentine Government of the Orcadas Observatory is very much to be desired, in view of the high southerly latitude of the observatory and the opportunities thus afforded for obtaining highly important data.

9. That every magnetic observatory publish annually the monthly and annual mean values of the magnetic elements observed during the preceding year, for the purpose of the mutual exchange of such results.

10. That the organizations responsible for the various magnetic services be urged to make prompt publication of their data as completely as circumstances permit.

11. That the Executive Committee be empowered to constitute the committees recommended by the section and to establish such additional committees as may be found necessary to put into effect the resolutions passed at the Rome meeting.

12. That the Executive Committee be authorized to incur the necessary expense for the publication in the most suitable form of the minutes and proceedings of the Rome meeting and of the various reports received, as well as for the issue of any additional publications which may be found desirable and which the available funds may permit.

13. That a committee be appointed to report on the best methods, instruments, and compilations for polar-light observations.

14. That in order to stimulate research regarding earth-currents, a committee be appointed to consider and report on the best methods and instruments.

15. That the Executive Committee be empowered to add to its membership or to the membership of the committees.

16. That it is desirable there should be in every country at least one observatory making systematic atmospheric-electric observations (especially of potential gradient, earth-air currents, conductivity, and number of ions), which are intercomparable amongst themselves and comparable with similar observations made in other countries.

17. That a committee be appointed on observational work in atmospheric electricity, to report on objects, instruments, and methods.

18. That in all publications concerning ionization, the author should indicate the value which he uses for the unit charge.

19. That, if funds allow, copies of disturbed magnetic curves continue to be published as at present, even when on a reduced scale, as they supply information at least potentially useful regarding the general features of disturbance. It is recognized, on the other hand, that for detailed examination photographic copies are much preferable, and that some

scheme might usefully be arranged whereby anyone desiring such copies could secure them from certain observatories for a prearranged fee. As a preliminary to such a scheme directors of observatories are to be consulted.

20. That regarding items A 6, 7, and 9 of the printed Agenda, namely, mean annual values and secular change, diurnal inequalities, and publications, the Executive Committee is to consider and formulate any recommendations they may think desirable.

(Signed) C. Chree, *President.*
(Signed) Louis A. Bauer, *Secretary.*

Researches of the Department of Terrestrial Magnetism (Vol. IV); Land magnetic observations, 1914–1920, by L. A. Bauer, J. A. Fleming, H. W. Fisk, and W. J. Peters, and special reports by J. A. Fleming, H. W. Fisk, and S. J. Barnett. Carnegie Inst. Wash. Pub. No. 175 (Vol. IV), 475 pages, 9 plates, and 17 text-figures (1921).

This volume contains, in continuation of the previous volumes of "Researches" (No. 175, Vols. I, II, and III), and in a similar manner, the results in two parts of magnetic observations made by the Department of Terrestrial Magnetism as follows: (*a*) The results of all magnetic observations made on land from January 1914 to December 1920, and (*b*) special reports on various special researches made by members of the staff of the Department.

The land stations for which the results are reported upon may be summarized as follows: Africa, 447; Asia, 356; Australasia, 315; Europe, 24; North America, 113; South America, 339; islands of the Atlantic Ocean, 19; islands of the Indian Ocean, 30; islands of the Pacific Ocean, 104. The total number of land stations is thus 1,747. The tabulation of results gives names of stations, geographic positions, values of the three magnetic elements, dates and local mean times of observations, references to instruments used, and the initials of observers.

Data for the determination of secular-variation have been obtained at 204 C. I. W. repeat localities, the reoccupations for each locality listed involving from 1 to 4 stations. The great majority, 168, of these were either exact reoccupations or close reoccupations (within less than 30 meters) and 36 were within less than 5 km. of stations previously occupied by the Department of Terrestrial Magnetism. For many of these localities the repeat observations were obtained not only at several stations, but also at different times during 1914 to 1920. In addition to these sources of secular-variation data, fully 150 more of the stations have been practical reoccupations (within less than 300 meters) or proximate reoccupations (within less than 5 km.) of stations previously occupied by various exploring expeditions.

The text preceding the tabulation of results gives a discussion of instrumental constants and corrections on adopted International Magnetic Standards as defined on pages 270–278 of Volume II of the Researches of the Department. (For abstracts of the investigations concerned with this portion of the text, see pp. 295 and 298.) A brief discussion of the accuracy of the geographic positions is given, particularly as regards longitudes. The full text of article on "Auxiliary tables to facilitate revisions of field magnetic observations," already abstracted on pages 313–314 of the Department's report for the year 1919, is given, together with graphs for determining without recomputation the corrections necessary in azimuth and time reductions for revised values of latitude or of time.

Somewhat extended extracts from the observers' field reports for the various expeditions are given. Following the field reports there are concise descriptions of the magnetic stations occupied during the period.

The second section of the volume contains special reports. Abstracts of these reports are given elsewhere in this report.

Results of comparisons of instruments for measuring the Earth's magnetic elements. Louis A. Bauer and J. A. Fleming. Phys. Rev., vol. 19, No. 4, pp. 427–428 (April 1922).

This paper, presented by the first author before the December 1921 meeting of the American Association for the Advancement of Science at Toronto, gives a résumé of intercomparisons of magnetic instruments at field stations and observatories obtained by the Department of Terrestrial Magnetism during 1905 to 1921. The resulting data, besides yielding information for the correlation and reduction of magnetic observations made by existing organizations, have yielded likewise results having important bearings upon the principles and methods of magnetic measurements. In conclusion were given the results of the comparisons at Washington, D. C., in 1921 between the previously adopted standard magnetometer of the Department and the recently constructed sine galvanometer, designed by Dr. Barnett, showing satisfactory agreement in the values of the horizontal intensity obtained by the two independent methods.

Proposed magnetic and allied observations during the total solar eclipse of September 21, 1922. Louis A. Bauer and J. A. Fleming, Terr. Mag., vol. 27, 83–85 (March–June 1922).

Attention is called to the unusually good distribution of magnetic observatories within the limits of the eclipse and on both sides of the belt of totality, there being six observatories north and five observatories south of the belt of totality, while there is one observatory located at points just before the beginning and just after the ending of the eclipse. The general scheme of work proposed is outlined, and includes magnetic, atmospheric electric, and meteorological observations. The general circumstances of the eclipse are given, as also the approximate local circumstances at seven points within the belt of totality. (See also p. 279.)

Report on the work of the Department of Research in Terrestrial Magnetism of the Carnegie Institution of Washington to January 1, 1922. Louis A. Bauer and J. A. Fleming. (Prepared for the Rome meeting of the International Section of Terrestrial Magnetism and Electricity, May 1922.)

This report summarized briefly the results obtained since 1904 by the Department under four general headings: (1) "Magnetic survey," including land, ocean, observatory, and special operations, (2) "Magnetic standards," (3) "Instruments," including land, ocean, observatory, and special instruments designed and constructed, and (4) "Publications."

Note on magnetic standards and comparisons of the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. Louis A. Bauer and J. A. Fleming. (Prepared for the Rome meeting of the International Section of Terrestrial Magnetism and Electricity, May 1922.)

This paper summarizes the work of the Department leading to the definition of the provisional "C. I. W. magnetic standards" adopted for its data through 1913 and of the provisional "international magnetic standards" adopted in 1914 by the Department. A brief account is given of the numerous comparisons during 1905 to 1921 at observatories and at Washington between instruments of many types, the results of which justify, for all practical requirements, the provisional standards adopted. The vital question concerning constancy of the standard instruments—C. I. W. magnetometer No. 3 and inductor No. 48—to which all comparisons are referred, is discussed and evidence submitted showing their unusually consistent performance throughout the period considered.

Further results of line-integrals of the Earth's magnetic force. Louis A. Bauer and W. J. Peters.[1] Phys. Rev., vol. 19, 428–429 (April 1922).

Line-integrals of the Earth's magnetic force around ocean areas. Louis A. Bauer and W. J. Peters.[2]

These two papers give additional results as derived from recent computations of line-integrals around circuits formed by the tracks of the magnetic-survey vessel, the *Carnegie*, and the trips of land expeditions sent out by the Department of Terrestrial Magnetism.

One of the most interesting circuits was that formed by Cruise III of the *Carnegie* in the North Atlantic Ocean in 1914, extending from New York to 80° north, off the northwest coast of Spitzbergen. This circuit embraces an area of 4,441,176 sq. km. The result of the line-integral around this circuit was such as would be produced by currents of positive electricity passing through the air perpendicularly through the Earth's surface of average strength one-twentieth of an ampere per square kilometer. For the sake of comparison it may be recalled that the line-integrals around the United States, as based upon independent computations of the magnetic data for 1905 and 1915, gave a result which could be produced by currents of positive electricity passing through the air perpendicularly through the Earth's surface, having an average strength of about one-thirtieth of an ampere per square kilometer (see Terr. Mag., vol. 25, 145–160, December 1920).

From the foregoing it is seen that the results of two line-integrals, one over an ocean area exclusively, and the other over a land area exclusively, are of the same sign and are practically of the same magnitude. On the other hand, the vertical currents as disclosed by atmospheric-electric observations, according to present methods, over the regions of the two line-integrals, agree in direction with the results of the magnetic line-integrals. Quantitatively, however, there is a pronounced discordance. The strength of the vertical conduction-current of atmospheric electricity is only about one ten-thousandth of the currents indicated by the magnetic line-integrals.

Another circuit for which the line-integral has been computed is that formed by the track of the *Carnegie's* first cruise, made in 1909–10. This circuit incloses an ocean area of 13,050,122 sq. km. and extends from New York to England along the track of ocean travel in latitude about 50° N., thence to Madeira, and finally back to New York by way of the sailing routes in latitude 20° N. The result of the line-integral around this circuit is the same as that which would be produced by currents of positive electricity passing from the air perpendicularly through the Earth's surface and having an average strength of one twenty-sixth of an ampere per square kilometer. This is practically the same result as was obtained by the evaluation of the line-integral around the United States.

The third line-integral is based upon a circuit by the *Carnegie* in the Indian Ocean, June 6 to September 9, 1911, extending across the Equator. The area inclosed is 11,125,474 sq. km., the resulting line-integral being practically zero. (The indicated upward positive current was less than one-thousandth ampere per square kilometer average strength.)

The fourth line-integral was computed for a circuit of the *Carnegie* extending across the Equator and inclosing an area of 13,538,751 sq. km. in the Pacific Ocean, from July 15 to October 22, 1912, and is especially interesting because of the comparative remoteness from continental masses. The result indicated an upward positive electric current of average strength of only nine-thousandth ampere per square kilometer.

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[1] Presented by Louis A. Bauer at the Toronto meeting of the American Physical Society, December 1921.

[2] Presented by Louis A. Bauer at the Rome meeting of the International Section of Terrestrial Magnetism and Electricity, May 1922.

The fifth line-integral is for the *Carnegie's* subantarctic cruise from December 7, 1915, to March 31, 1916, between the parallels 40° and 60° south, and inclosing a polar area of 50,236,934 sq. km. This circuit incloses a region high and mountainous in the center, of perpetual snow and glaciers, where winds of unusual force prevail and where the atmospheric conditions are considerably different from those of the previous cases. The line-integral indicated an upward positive electric current of average strength one-sixtieth ampere per square kilometer.

The results of the line-integrals for these five ocean areas are in general accord with those given in the first author's 1920 paper (Terr. Mag., vol. 25, pp. 151–156, December 1920). They show a consistent and possibly a significant geographical distribution in magnitude as well as algebraic sign.

An investigation was likewise made as to what extent certain assumed errors in the data used for the calculation of these line-integrals would affect the final result. It was found that accidental errors of observation even larger than might be expected would not effect the values of the integrals materially. Mr. Ennis and Miss Tibbetts assisted in all these computations.

Dip-needle errors arising from minute pivot-defects.[1] H. W. Fisk. Special report in Vol. IV of Researches of Department of Terrestrial Magnetism, Carnegie Inst. Wash. Pub. No. 175, Vol. IV, 359–371, 10 text-figures (1921).

In determining inclination by means of a dip circle, four needles are ordinarily used. There is reason to believe that there is a constant correction that applies to a given instrument with a specified set of needles, and there are, furthermore, characteristic variations among individual needles probably arising from mechanical imperfections. These are found to vary slightly with the magnetic field and may be determined by least-square reductions when data are sufficient.

It often occurs that within a limited range of inclination a needle will give results that do not harmonize with its general behavior, and it has been the practice to reject such erratic values. In this paper a special study has been made of certain cases of this kind, and it has been found that the erratic values do not occur indiscriminately, but the corrections required to bring them into harmony with the other needles take a symmetrical form resembling a sine-curve when plotted for the range of inclination over which the erratic values are found. This range is, in general, about 4° or 5°, and the amplitude of the correction-curve represents from 6′ to 10′. This form of curve suggested the possibility that the trouble was caused by a minute particle adhering to the pivot. A theoretical discussion is made of the effect of such a particle under varying conditions, and the results are compared with those found from the observations. The general correspondence between the theoretical and observed results leads to the conclusion that minute rust-particles, which may suddenly appear and later disappear, may be of the form and magnitude required to produce the observed effects.

A series of diagrams and graphs accompanies the article, and a table is given illustrating the method used in analyzing the observational data in order to separate the affected value from the others.

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[1] A paper under this title was also presented before the Philosophical Society of Washington on November 19, 1921; see Jour. Wash. Acad. Sci., vol. 12, 21–22 (January 4, 1922).

Construction of non-magnetic Experiment Building of the Department of Terrestrial Magnetism. J. A. Fleming. Special report in Vol. IV of Researches of the Department of Terrestrial Magnetism. Carnegie Inst. Wash. Pub. No. 175, Vol. IV, 351–358, 1 plate, 2 text-figures (1921).

This report gives a detailed description of the Experiment Building, designed for special investigations in magnetism and completed in 1920. The desiderata considered essential, and upon which the plans were based, were (*a*) unusual rigidity and strength, (*b*) non-magnetic construction, and (*c*) insulation against sudden temperature changes. It was decided to adopt a concrete double-wall construction, using brass reinforcement, with a continuous insulating dead-air space 2½ inches thick between the two 6-inch walls. Further provision for protection against rapid changes of temperature outside the building was provided for by double windows and double doors, and by a double ceiling. The general lines of the building were made to conform architecturally with those of the Standardizing Observatory already on the site. (For views of buildings see Annual Report for 1920, opposite p. 304.)

The equipment for use of the building as a laboratory is described in detail. The non-magnetic requirement made it, of course, more difficult to provide suitably for heating the building, for gas, water, drain, and compressed-air pipe-lines, and for the necessary electric switchboards and installations. The various pipe-lines and electric cables all lead underground in a concrete tunnel from the main laboratory. Provision for mounting of galvanometers and other instruments was made by the use of 2-inch thick soapstone shelves mounted on heavy wooden brackets built into the walls of the building. A brief summary of the specifications for the construction is given. The cost of construction work was about 30 cents per cubic foot of volume inclosed.

The results of tests made in March 1920 to determine the magnetic field in the completed structure show that the requirement for non-magnetic construction was practically attained, the small linear variation in the magnetic elements from the south end to the north end of the building being attributable largely to the proximity of the main laboratory with its great mass of magnetic material, and to the slightly magnetic character of the soil used in grading about the outside of the building.

Latest annual values of the magnetic elements at observatories. J. A. Fleming. Terr. Mag., vol. 26, 146–149 (December 1921).

A compilation of the most recent annual values of the magnetic elements at observatories distributed over the Earth.

Results of comparisons of magnetic standards, 1915–1921. J. A. Fleming. Special report in Vol. IV of Researches of the Department of Terrestrial Magnetism. Carnegie Inst. Wash. Pub. No. 175, Vol. IV, 395–475 (1921).

This report is in continuation of the special report by Louis A. Bauer and J. A. Fleming contained in Volume II of the Researches of the Department (pp. 211–278). The direct comparisons of magnetic standards include results at the following observatories: Agincourt, Canada; Cheltenham, United States; Eskdalemuir, Scotland; Stonyhurst, England; Greenwich, England (2 series); Kew, England (2 series); Honolulu, Hawaii (2 series); Hongkong, China; Rio de Janeiro, Brazil (2 series); Pilar, Argentina (2 series); Apia, Samoan Islands (2 series); Christchurch, New Zealand (5 series); Loanda, Angola; Tananarive, Madagascar; Lukiapang, China; and Watheroo, Western Australia. These direct comparisons are amplified further by indirect comparisons resulting from comparisons obtained by other organizations, including particularly the following: (*a*) Results obtained by the superintendent of the Eskdalemuir Observatory during 1913[1] at Greenwich, Kew, Falmouth, Valencia (Cahirciveen), Eskdalemuir, De Bilt, Potsdam, and Val Joyeux, and (*b*) results reported upon by Dr. L. Palazzo[2] at Parc St. Maur and Kew in 1898, and at Potsdam and Pola in 1902.

In general, for those observatories where previous comparisons had been obtained, there is a good agreement in the resulting values of corrections on standards. In some cases rather large corrections on standards have been determined; these apparently are caused by changes in the instrumental constants which have developed since the original determinations of the constants.

The report concludes with a general discussion of the results thus far obtained by the Department of Terrestrial Magnetism and as to the accuracy attainable. A discussion of the absolute standard in horizontal intensity, H, as deduced from the results of the extended comparisons between standard magnetometer No. 3 and sine galvanometer No. 1 of the Department of Terrestrial Magnetism follows. It appears that absolute standards for the three magnetic elements are readily attainable with well-designed instruments and carefully determined constants within 0.′1 or 0.′2 in declination and inclination, and within $0.00015H$ in horizontal intensity.

Progress report of Committee on Magnetic Standards, and Instruments and Methods for Aerial Magnetic Measurements.[3] J. A. Fleming.

This report summarized the developments since the last annual meeting of the section in magnetic and electric methods of determining the horizontal intensity of the Earth's magnetic field. Brief accounts were given of electrical instruments designed by Dr. N. Watanabe in Japan, by Sir Arthur Schuster and Mr. F. E. Smith in Great Britain, and by Dr. S. J. Barnett in America, together with accounts of comparisons of these instruments with magnetometers. The final results of comparisons obtained in Japan and Great Britain have not yet been communicated. The comparisons of the standard in horizontal intensity adopted by the Department of Terrestrial Magnetism in 1914, tentatively designated "International Magnetic Standard" and defined by C. I. W. magnetometer No. 3, with that determined by the electric method defined by C. I. W. sine galvanometer No. 1, showed a difference between the two instruments of only $0.00004H$, the probable error of the mean difference being $\pm 0.00003H$. While the close agreement indicated is partly accidental, the knowledge of the constants of the respective instruments is such as to indicate an agreement of the standard determined by the magnetic method with that determined by the electric method to be well within the allowable limits of error both for observatory and field use.

The report abstracted also the results of direct comparisons obtained during 1915 to 1921 at 20 observatories, the compilation confirming the provisional International Magnetic Standards of the Carnegie Institution of Washington as being correct well within the magnitude of unavoidable errors of observation and of the determination of constants of the various types of instruments used. The necessity, however, of careful control of constants by comparisons with reliable standards at least once every two or three years was emphasized, as also the necessity of having control observations from time to time on the moment of inertia used for the oscillating magnet of the magnetometer.

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[1] *British Meteorological and Magnetic Yearbook*, Part IV, section 2, 1913 (83–84).

[2] Misure magnetiche e confronti magnetometrici a Terracina, *Ann. Uff. centr. meteor. geodin*, vol. 27, Part I, Rome 1920 (1–33).

[3] Membership of committee: C. G. Abbot, J. P. Ault, S. J. Barnett, J. A. Fleming, chairman, and J. T. Watkins

The report was concluded with a brief account of the development of aerial instruments, particularly the design of magnetic instruments for direction and position purposes at the United States Bureau of Standards. The desirability of concentrating attention on the design of suitable apparatus for precise determinations of the magnetic elements on airships was emphasized as of first importance in undertaking investigations of variations of the magnetic elements with height.

Earth-currents: Methods and equipment, with special reference to the Watheroo Magnetic Observatory, Western Australia. O. H. Gish.

Beginning in March 1922, most of the writer's time was devoted to the various matters pertaining to the design and installation of a system for the measurement of earth-currents. Although this system was designed specifically for the Watheroo Magnetic Observatory, the investigations and much of the design will be equally applicable to such other systems as the Department may install in the future. In this connection the literature of the subject was reviewed with special reference to methods and such analyses were made as seemed required in outlining plans for the observational equipment and program. Then followed correspondence, conferences, and other investigations in order to determine upon recommendations for design and installation details. Some laboratory experiments with nonpolarizing electrodes indicated that this type is open to serious criticism and, consequently, further investigation of electrodes is urgently needed. The more important features of the general plans that have been developed and of the equipment designed are outlined in the paragraphs that follow.

A complete plan for the study of earth-currents must provide not only for the observation of earth-currents but also for that of phenomena that may be corelated. The latter have been already largely provided for at the Watheroo Observatory, but there remain two elements that should receive attention because of their likely bearing on earth-current records, namely, soil temperatures and soil moisture. An experimental well, equipped with a water-level recorder, might suffice to show fluctuations in the last-named element.

In the measurement of earth-currents direct methods can not be used, but the magnitude and direction of these currents must instead be determined from measurements of earth-current potentials and earth-resistivity. The method of obtaining the latter has been outlined, but further development must be deferred until next year. For the present year, then, the chief concern is with methods and equipment for the measurement of potentials. Such is the chief purpose of the earth-current system or lines.

The system most frequently used consists of three earthed points, preferably so placed that they may be the vertices of a right-angled triangle. The point at the vertex of the right angle is used as a common reference or zero-point in measuring the potentials of the other two. Lines connect each of the other points to the common point through appropriate measuring instruments. Such a system is the simplest that has yet been devised for determining the magnitude and direction of earth-currents, but in using it, one is compelled to make the highly restrictive assumption that the equipotential surfaces are parallel planes perpendicular to the horizon plane. To detect lack of parallelism or curvature in these surfaces a more elaborate surface distribution of potentials than can be obtained from three points is needed; while to detect a departure from perpendicularity a distribution with depth must be obtained. In the design of this first installation, however, the simpler system was rather closely adhered to, although provisions are made so that, in case it seems advisable later to provide for obtaining a better distribution of potentials, nothing of the present system need be sacrificed.

The *best type of earth-current line* would, from our investigations, seem to be one having subterranean lines consisting of leaded rubber-covered cable laid about 18 inches deep in insulating conduit. In addition to its much longer life, this type of installation should be nearly free from thermoelectric effects, should have better line insulation, etc. To offset these advantages, however, the first cost is considerably greater than for the more common aerial type. Furthermore, since no direct comparisons between aerial and subterranean lines have thus far been reported by other investigators, it seemed advisable that at the outset of our earth-current studies we should provide lines for obtaining such comparisons. These should be of value not only for our guidance in the future, but also should aid us in more correctly appraising the results already obtained by other investigators. For the furtherance of this purpose two miles, one mile on each arm of the earth-current system at the Watheroo Observatory, are to be provided with both aerial and subterranean lines, so that either pair of earth-plates may be connected through the recording instrument by overhead and underground lines alternately at short intervals. Another feature is a second and longer aerial line which extends along each arm of the system for a distance of 2 miles instead of 1. This will serve two purposes. One is to compare the relative merits of the longer and shorter aerial lines and the other is that, when used in conjunction with the shorter line, it will furnish the evidence necessary for determining whether the simpler "three-point" systems will suffice, or whether a more elaborate distribution of earthed points is needed.

The recording instrument to be employed is a Leeds and Northup multiple-point curve-printing recorder which can be used to full advantage on the simpler three-point system, but is also applicable to systems of as many as 12 points. With special features which have been provided, this instrument should meet all the requirements of the earth-current potential measurements at Watheroo, unless the magnitudes found there prove to be very much different from those that have been obtained elsewhere. The potentiometer, employing as it does a null method, will practically eliminate polarization of the electrodes.

The selection of earth-plates or electrodes will involve further experimental investigation. Nearly as many types have been recommended as the number of investigators using them. The nonpolarizing electrode, as our preliminary tests indicate, probably introduces more spurious effects than it eliminates when used in a fixed system. Some preliminary field tests were made in August at the Cheltenham Magnetic Observatory, Maryland, primarily to determine the requirements of instruments for special investigations in the field but the opportunity was used also to observe electrode characteristics. It was noted that marked changes in the potential difference between earthed electrodes could be produced by the addition of water to the soil in their immediate vicinity and by mechanical agitation of the electrodes.

Comparisons in the laboratory of various electrode materials and of types of electrodes, though as yet not definitive, would indicate that metallic electrodes, probably of lead or iron, will prove most satisfactory in fixed systems designed for continuous recording at observatories. Such electrodes if used must, however, be checked periodically against some standard. Investigations leading to the design of such a standard and the method of using it are now under way.

A rotary slide-wire for producing uniform variation in potential difference. S. J. Mauchly. J. Opt. Soc. Amer. and Rev. Sci. Instr., vol. 6, No. 8, 852–858 (October, 1922).

One of the requirements in the calibration of the recording conductivity-apparatus in use at the atmospheric-electric observatories of the Department of Terrestrial Magnetism is a device for varying the potential difference between the two members of a condenser at a constant and definitely known rate.[1] The paper describes a special form of "rotary potentiometer" which was devised for the use indicated and constructed in the instrument shop of the Department.

The slide-wire proper consists of about 25 meters of wire wound in a screw-cut groove on a marble cylinder 10 cm. long and 10 cm. in diameter. The cylinder is caused to turn on its axis by means of a small direct-current motor which is energized by a storage battery. The traveling contactor consists of a small grooved wheel which engages the spiral slide-wire and slides along its own axis, which is parallel to the axis of the cylinder. The reduction gears between the motor and cylinder and the other speed controls are such that the time required for the contactor to travel the entire length of the cylinder may be as short as 5 minutes and may be increased to 25 minutes. A tachometer attached to the motor-shaft makes it possible to determine both the speed of rotation of the cylinder and the degree of constancy at which this speed is maintained.

With the apparatus described it has been found possible to vary the potential difference between the traveling contact and either end of the slide-wire at rates ranging from very small values up to about 0.1 volt per second and to maintain constancy of rate to 1 part in 250.

The paper is illustrated by 4 figures, which include 2 photographic views, schematic diagram of connections, and a reproduction of drawings showing the more important details of construction.

The atmospheric-electric instrumental equipment for the observatories of the Department of Terrestrial Magnetism. S. J. Mauchly.

The program at the observatories of the Department of Terrestrial Magnetism at Watheroo, Western Australia, and at Huancayo, Peru, contemplates continuous records of the atmospheric-electric elements in addition to those of terrestrial magnetism. The required electrographs so far designed by the Department and constructed in its instrument-shop are for photographic registration of electric potential-gradient and conductivity of the atmosphere. Designs are under way also for equipment to record photographically and continuously the ionization of the atmosphere. The essential features of the potential-gradient and conductivity apparatus may be briefly described as follows:[2]

The potential-gradient apparatus is essentially a quadrant electrometer with needle connected to an insulated ionium collector. The collector is supported 1 meter outside the wall of the atmospheric-electric house at a height of 2.4 meters above the ground. The electrometer and the battery connected to its quadrants are contained in a dust-proof and insect-proof metal housing. The rod supporting the collector, together with its connection to the electrometer is mounted in the axis of a tube of large diameter supported in the wall. The air surrounding the exposed face of the insulator near the outer end of this tube is kept constantly above the dew-point by a small electric heating-coil.

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[1] See "An apparatus for automatically recording the electrical conductivity of the air," by W. F. G. Swann, in "Annual report of the Director of the Department of Terrestrial Magnetism" for the year 1917, Year Book of the Carnegie Institution of Washington, 1917, p. 279. As indicated in the paper referred to, a preliminary form of the apparatus here described was used by Dr. Swann in 1917.

[2] Complete descriptions of these instruments and of installations with illustrations will appear n the *Journal of Terrestrial Magnetism and Atmospheric Electricity.*

Automatic records of the base-line and of the insulation are obtained several times daily. The method used for these controls may be described as follows: Just outside the end of the outer insulating support for the collector rod, but still within the supporting tube referred to above, a rigid sulphur insulator is introduced in the collector rod; this insulator is bridged across by a mercury-contact device, the contact being broken several times daily by means of an electromagnet so as to insulate the last section of the collector rod (including the collector) from the remainder of the system. This condition is maintained about 12 minutes, the electrometer system being automatically grounded for one minute at the middle of the interval; thus the photographic record, before the earth contact is made, will indicate the state of insulation of the main system on the assumption that the special insulator is functioning properly, while the record obtained after the earthing will indicate to what extent the exposed insulators may be defective. This procedure eliminates the uncertainty usually existing as to whether the recorded minima relate to the potential gradient or to the humidity and other conditions affecting the insulation.

The conductivity apparatus is a duplex system consisting of separate units for photographically recording the positive and negative conductivity. Each of these units is a modification of the Gerdien conductivity apparatus similar in general to that described by Swann,[1] but including various features and improvements resulting from several years' experience with the original apparatus. In this form the records are obtained by means of a quadrant electrometer and accessories.

One pair of quadrants of the electrometer is connected to the insulated central cylinder and the other to the case of the electrometer, which is maintained at a potential of the order of 100 volts. The two pairs of quadrants are permanently connected through a high-resistance radioactive cell of the type developed by Swann and the author (*Terr. Mag.*, vol. 22, pp. 1–21, 1917), and the apparatus is readily adjusted for a linear relation between electrometer deflection and conductivity. Provisions are made also for frequent calibrations (see p. 302 and *J. Opt. Soc. Amer. and Rev. Sci. Instr.*, vol. 6, pp. 852–858) and for elimination of spurious leak-effects by methods similar to those described originally by Swann.[2] To eliminate effects arising from radioactive materials in the atmosphere, which are deposited on the wall of the air-flow tube or on the insulated central cylinder, the air is caused to pass first through an auxiliary condenser of large capacity; the auxiliary condenser is ordinarily earthed, but once each hour is charged to a potential several times as high as that on the main cylinder.

The outer member of the main pair of concentric cylinders of each unit forms the middle section of a vertical air-flow tube extending through both the roof and the floor. Air is taken in through a suitable hood above the roof and discharged into a space between the raised floor and the ground. There is thus little chance of air being drawn a second time through the apparatus, and the maintenance of satisfactory insulation is greatly facilitated by the fact that dust and spray from the air-stream are prevented from depositing on the insulators of electrometers and accessory apparatus. Especial care has been taken in the design to secure accessibility and easy removal of all parts requiring occasional inspection and cleaning. Furthermore, all parts are of standard dimensions to expedite repairs and replacements. The arrangement of the recording drums is such that the approximate value of a given element may be determined at any time. The fans which draw the air through the conductivity apparatus are driven by small electric motors operated on 32 volts from storage batteries. Electric recording lamps are also used. The batteries, generator, and gasoline motor are separately housed far enough away from the atmospheric-electric house to prevent any disturbance from fumes.

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[1] See Annual Report of the Director of the Department of Terrestrial Magnetism, Year Book of the Carnegie Institution of Washington for 1917, p. 278.

[2] See Annual Report of the Director of the Department of Terrestrial Magnetism, Year Book of the Carnegie Institution of Washington for 1917, p. 279.

The essentials of the building designed by Mr. Fleming for the installation of the atmospheric-electric apparatus, to be described in greater detail elsewhere, include (*a*) substantial and rigid construction to eliminate deleterious vibration effects from operating motors, (*b*) moderate temperature ranges in the observing room without artificial temperature control, (*c*) arrangements such that the air passed through the air-flow tubes of the aspiration apparatus shall be exhausted outside of the building in such a manner as to prevent its again entering the apparatus, (*d*) arrangements for properly grounding the entire outer surface of the building, and (*e*) provision of ample floor space for installation of apparatus for the atmospheric-electric elements referred to above and for additional installations for atmospheric-electric and earth-current equipment.

These requirements are met by the use of reinforced concrete. The recording room is 3.7 by 5.5 by 2.1 meters (12 by 18 by 7 feet) inside dimensions, with double walls and double roof (5-cm. continuous air-spaces between) and heavy concrete floor built 0.4 meter above a concrete slab at ground-level. The building is provided with a louvered wooden wall on three sides 0.5 meter from the concrete walls; on the fourth side this louvered wall is about 1 meter distant from the concrete walls of the building to provide suitable entry to the observatory and a small room for necessary laboratory and repair work, as well as for the storage of photographic paper, etc.

Atmospheric electricity: Preliminary report on the diurnal and annual variations of the potential gradient from observations at Washington, D. C., during 1918. S. J. Mauchly.

The Department of Terrestrial Magnetism has, since 1916, maintained an experimental atmospheric-electric observatory on the deck of its Laboratory in Washington. Although primarily for experimental and instructional purposes, it has been possible also to obtain continuous photographic records of the variations of the potential gradient, as indicated by a quadrant electrometer connected with an insulated ionium collector, for nearly the entire time since January 1917. The observatory is located several miles to the northwest of the city proper and surrounded mainly by second-growth woodland with occasional clearings. While the site is not ideal for the location of a permanent observatory, it has seemed desirable to make a reduction of the records obtained, since they constitute the longest series of continuous records of the potential gradient which have thus far been obtained in North America.

The reductions under way include all the records obtained, but the remarks which follow refer only to results derived from daily records free from negative potentials and complete for 24 consecutive hours beginning at midnight, 75th meridian mean standard time. The results are for recorded potentials only, no account having been taken of the factor for reducing to absolute values in volts per meter, and its possible diurnal and annual variations. On the assumption that the *variations* of the potential gradient are essentially the same as the variations of the recorded potentials, the results for 1918 may be briefly stated as follows:

(*a*) The mean diurnal-variation curve for the entire year, derived from 136 selected days, shows a strong maximum about 2 hours before noon and a weak secondary maximum about 7 hours after noon. This is in rather marked contrast with the corresponding curves for Kew and Potsdam, which show very little difference between the forenoon and late afternoon maxima. In this respect the Washington curve more nearly resembles the 1918 potential gradient curve for Tortosa, except that the times of occurrence of the primary and secondary maxima are approximately interchanged.

(*b*) During the summer months the mean diurnal variation from the Washington records for 1918 is similar to that at Kew, Potsdam, and Tortosa.

(*c*) The chief difference between the diurnal variation of the potential gradient at Washington as compared with the European stations already mentioned occurs in the winter months. Here the secondary maximum (about 7 p. m.) is almost entirely suppressed, while the principal maximum continues to appear about 2 hours before noon, and the principal minimum shortly after midnight. Thus, in winter the predominating maximum not only is more pronounced than at Kew and Tortosa, closely resembling in this respect the winter curve for Potsdam, but also it occurs some 8 or 9 hours earlier in the day at Washington than at the other stations named.

(*d*) The annual variation of the recorded potentials during 1918 followed very closely the annual variation of the potential gradient at Kew and Potsdam for the same year, in being both more pronounced and more regular than the annual variation at Tortosa. The maximum occurred in January and the minimum in August. On the basis of an approximate reduction-factor, it is estimated that the mean value of the potential gradient for the year 1918 was about 200 volts per meter. The estimated values for January and August were about 250 and 125 volts per meter, respectively.

Results from a single year are, of course, not conclusive, and it is quite possible that the results for the entire 6-year period (1917–1922, inclusive) may show considerable variations in detail from those for 1918. The dependence of the results upon the immediate surroundings of the observatory and the constancy of the reduction-factor are also matters which require further investigation. However, in view of the results obtained from observations aboard the *Carnegie* (see Year Book for 1921, p. 354), no small interest will attach to the comparison of the ultimate diurnal-variation results at Washington with those obtained at other stations for the same period.

Progress report of the Committee on Earth-Currents and Polar Lights.[1] S. J. Mauchly.

The report deals primarily with plans considered by the committee for stimulating interest in earth-current and polar-light investigations and increasing the number of reliable observations.

On account of the rather extensive equipment required for suitably controlled earth-current observations, it seems desirable to urge the importance of such work upon institutions and organizations having adequate facilities rather than to encourage a large amount of work on the part of individual observers whose equipment is likely to be inadequate.

Since no systematic earth-current data are available for the American continent, it is suggested that information of some value could probably be obtained by a study and coordination of data regarding earth-currents observed on the lines of telegraph, telephone, and cable companies.

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[1] Presented at the annual meeting of the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union, Washington, March 7, 1922. Members of the committee: J. H. Dellinger, A. J. Henry, A. G. McAdie, S. J. Mauchly, chairman, A. G. Mayor, and W. E. Parker.

Further observations are urged for determining whether or not vertical currents exist in the Earth's crust; similarly, the need is emphasized for the investigation of electric currents in the sea.

Polar-light investigations are considered under the following heads:

(1) Determination and study of physical characteristics and properties.
(2) Time variations and geographic distribution.
(3) Interrelations with terrestrial magnetism, atmospheric electricity, and solar phenomena.

For the proper study of the *physical characteristics* we shall have to look mainly to Störmer, Vegard, and others who are properly *located* and *equipped.* Such work, as in the case of earth-currents, is not well adapted to the efforts of volunteers and casual observers. The case is somewhat more favorable as regards spectroscopic observations, and here it seems desirable to enlist the attention and effort of such observatories as are favorably located.

As regards observations for determining the time *variations* and the *distribution* of auroræ, and the *interrelations* between auroræ and terrestrial magnetism, terrestrial electricity, and solar phenomena, there apparently exists a large amount of observational data in the meteorological bureaus of various countries, especially in Canada, the United States, Australia, and New Zealand, which could be used to considerable advantage. It should also be possible to interest volunteer observers in favorable locations, especially at observatories, to supply most helpful data for certain phases of the study of polar lights. In this connection it is noted that one of the most important conditions for successful work by cooperative volunteer observers is that they may be given such assistance as will enable them to know, definitely, what is wanted.

Attention is directed to the importance of securing the cooperation of observers in the Southern Hemisphere and the desirability of arranging all suitable data in the form of a polar-light catalog.

Earthquake records on the Eschenhagen magnetograms at the Watheroo Magnetic Observatory, Western Australia, August 13 and 23, 1921. W. C. Parkinson. Terr. Mag., vol. 26, 137 (December 1921).

This article gives a brief account of earthquake effects recorded at the Watheroo Magnetic Observatory, Western Australia, on August 13 and 23, 1921, together with notes of disturbances indicated on the Milne seismograms at the Perth Observatory, communicated by Government Astronomer H. B. Curlewis.

Dynamic and tilting deviations. W. J. Peters.

An investigation was begun by making an analysis of certain simultaneous records obtained with the standard compass and the deflector on the subantarctic cruise of the *Carnegie*, harbor swings, and observations in the vicinity of the magnetic equator. The analysis revealed small systematic discrepancies and indicated the desirability of testing the instruments in a uniform magnetic field on shore. They were accordingly mounted in the same relative positions at the Standardizing Magnetic Observatory, Washington, that they have on board the *Carnegie* during a swing, in order to determine if any part of the discrepancies were caused by the metal binnacles, bowls, or accessories, or by any one instrument upon the other. The experiments were made with the assistance of Mr. H. F. Johnston and showed satisfactorily that the binnacle and accessories are practically free of iron and that there is no mutual effect between the instruments.

Experiments also were made with the standard compass on a harmonic-motion table where the instrument may be given simple harmonic motion in a plane. No deviation was found for one of the conditions of maximum dynamic deviation, namely, for the condition that the period of compass swing and the period of the simple harmonic motion are equal. Mechanical difficulties, however, which will probably be overcome, in the operation of the table preclude any final conclusions at the present time.

An experimental compass was designed to study dynamic and tilting deviations by eliminating one or the other as desired in the laboratory experiments.

Results of Magnetic Observations on the *Maud* Expedition, 1918–1921. H. U. Sverdrup and C. R. Duvall, with introduction by Roald Amundsen. Terr. Mag., vol. 27, Nos. 1 and 2, 35–56 (March–June 1922).

In a brief introduction, Captain Amundsen emphasizes the value to the *Maud* Expedition of the cooperation of the Department of Terrestrial Magnetism. He lays special stress on the loan of the most suitable instrumental equipment, on the early publication of the results, and on the advantage of Dr. Sverdrup's association with the Department, not only to this publication but also to the future work of the expedition.

In April 1918, Captain Roald Amundsen and Dr. Fridtjof Nansen met with Dr. L. A. Bauer in Washington to discuss plans for magnetic work on Captain Amundsen's forthcoming *Maud* Expedition. Guided by the Arctic experience of Captain Amundsen, Dr. Nansen, and Mr. Peters, a member of the Department, it was decided that magnetometer No. 8 and Dover dip-circle No. 205, with certain minor modifications, would be best suited for magnetic observations in the Arctic.

After modification in the shops of the Department, under Mr. Fleming's direction, these two instruments, together with numerous accessories and complete instructions for observing according to the Department's methods, were supplied to the *Maud* Expedition. For making magnetic measurements, the expedition also had, besides these instruments, Dover land dip-circle No. 154 and a Toepfer and Son photographic registering declinometer.

The *Maud*, Captain Amundsen's ship, constructed especially for navigation in the icy seas of the Arctic, sailed from Vardö, Norway, July 18, 1918. Captain Amundsen's intention was to follow the Arctic coast of European and Asiatic Russia as far east as 165° E., then to proceed northward until the *Maud* was frozen into the polar drift. While drifting across the Polar Sea, it was planned to make oceanographic, meteorological, and magnetic observations.

During the three summers of 1918, 1919, and 1920, the *Maud* made every effort to reach the desired longitude on the coast, and then to force her way into the large drifting ice-fields to the north. The early freeze of each succeeding fall found her still struggling with the coastal ice, and so the three winters were spent frozen fast in the fixed ice on the Siberian coast.

The first winter, 1918–19, the *Maud* was frozen in within 200 meters of the shore-line on the east coast of the Chelyuskin Peninsula, in longitude 105° 40′ E. The second winter she was at Ayon Island, in longitude 167° 43′ E., and the third winter, at Cape Serdze Kamen, in longitude 171° 39′ W.

Except for two stations occupied at Jugor Strait and one at Port Dickson in the summer of 1918, all the magnetic observations of this expedition were made while the *Maud* was frozen fast during the three successive winters. Besides the observations at the winter-quarters stations, other magnetic stations were established on numerous sledge trips, extending up to several hundred miles in some cases. The majority of stations occupied on these trips are on or near the coast, the farthest station being about 75 miles inland.

At the first winter-quarters station an observatory was built for the magnetometer and dip-circles, and a connected building for the photographic declinometer. Observations were made here from October 1918 until August 1919. Magnetometer and dip-circle results here total 181 values of declination, 121 of inclination, and 227 of horizontal intensity. Sixteen additional stations were established on sledge trips in the surrounding region, comprising the Chelyuskin Peninsula and extending northward to Crown Prince Alexei Islands.

When the *Maud* succeeded in getting away from her first winter quarters, two members of the crew were left behind, with all the original records of the first winter's observations, which they were to carry by sledge to Port Dickson. It now appears that these men unfortunately have been lost. The absolute results of this winter's work have been computed from copies kept on board the *Maud*, but there were no copies of the photographic registrations.

During the second winter the magnetic instruments were mostly used on the sledge trips. In addition to the winter-quarters station, 19 others were occupied, the most distant one being 700 miles away at Bering Strait. Again, the third winter, nearly all the magnetic observations were made on sledge trips. On one trip lasting 69 days, 1,200 miles were covered and 11 magnetic stations occupied.

In all, 53 stations appear in the condensed table of results. Nos. 22 and 42 are identical, while in several instances stations are very near each other. Examples of close stations are Nos. 21 and 40 and Nos. 34 and 38. On the Chelyuskin Peninsula, also, the stations are rather close together in some cases.

At 19 of the 53 stations, declination, inclination, and horizontal intensity were measured. At 32 of the other 34 stations only the two elements, inclination and horizontal intensity, were observed, while at two stations there was only inclination.

Values of the magnetic elements in the table of results are based on international magnetic standards. This has been secured in a satisfactory manner by means of comparison observations with the standards of the Department of Terrestrial Magnetism both before the expedition and after the return, as well as by intercomparisons by the observers in the field.

The magnetic results of the expedition, compared with those of Nordenskiöld for 1878 and 1879 and of Nansen for 1893, furnish valuable secular-variation data for the Siberian coast.

Meteorology on Captain Amundsen's present Arctic Expedition. H. U. Sverdrup. Monthly Weath. Rev., vol. 50, 74–75 (February 1922).

This paper gives a brief account of the meteorological observations taken during the three years 1918 to 1921, spent on the north coast of Siberia, and a brief outline of the plans for the meteorological work on the contemplated drift of the expedition's vessel, the *Maud*, beginning in 1922, across the Arctic Sea. During the drift, barometric pressure, temperature, humidity and wind are to be registered continuously, and the registrations are to be checked by three daily observations. Investigation of the upper air-currents by means of pilot balloons and kites is to be made. Meteorological observations are also to be made on the airplanes used for geographical exploration. Daily weather reports are to be forwarded from the vessel by wireless, it being hoped to keep in communication with Nome during the first part of the drift and with Spitzbergen during the last part.

Customs of the Chukchi natives of northeastern Siberia. H. U. Sverdrup. Jour. Wash. Acad. Sci., vol. 12, 208–212 (April 19, 1922).

This paper was read February 16, 1922, at a joint meeting of the Washington Academy of Sciences and the Anthropological Society, and summarized the author's observations on natives of northeastern Siberia while a member of Captain Amundsen's Arctic Expedition on the *Maud* during 1919 to 1920. Upon Captain Amundsen's suggestion, the author spent seven and one-half months from September 1919 with a tribe living about 700 miles west of Bering Strait, taking advantage of the unique opportunity afforded for gathering information regarding this little-known tribe while the *Maud* was in winter quarters. The author accompanied the tribe from its summer quarters at Ayon Island to its winter quarters in the sheltered forests in the interior, rejoining the expedition in the spring.

The scientific work of the present Amundsen Arctic Expedition.[1] H. U. Sverdrup. Jour. Wash. Acad. Sci., vol. 12, 270–271 (June 4, 1922).

An account was given of Captain Amundsen's *Maud* Expedition during 1918 to 1921 and of the results obtained, including magnetic observations (see pp. 307–308), registrations of meteorological elements, tidal observations, and information of ethnological interest obtained by the author during the winter spent with the Chukchi tribe of northern Siberia.

Because of necessary repairs, the vessel of the expedition had to proceed in the summer of 1921 to Seattle. A brief account was also given of the scientific program which it is hoped to carry out during the continuation of the expedition's work beginning in July 1922. In addition to the magnetic, atmospheric-electric (potential-gradient), polar-light, and meteorological observations, it is planned to make an extensive series of oceanographic determinations and measurements of nocturnal radiation. It is expected also that there will be some opportunity to take gravity observations over deep sea, but under conditions similar to those in solid ground. Astronomical observations as necessary in connection with the determination of drift course and geographical explorations will also be carried out.

Hall effect and specific resistance of silver films. G. R. Wait, Phys. Rev., Vol. XIX, 615–622 (June 1922.)

This paper gives the results of an investigation carried out at the Physical Laboratory of the State University of Iowa on the Hall effect and specific resistance of silver films, 200 to 20 $\mu\mu$ thick. In agreement with previous results, the specific resistance increased more and more rapidly with decreasing thickness, becoming infinite for about 20 $\mu\mu$. On the other hand, the Hall coefficient was found to be the same in the films as in the bulk metal. The thicknesses were computed from the weight of silver in each film, assuming the density that of the bulk metal. The films were obtained by chemical deposition.

After discussing various proposed theories of electrical conduction in thin films in the light of the above results, it is concluded that these and other facts are in harmony with the simple conception that the film consists of granules, each having the properties of the bulk metal, and that conduction occurs only along strings of granules in contact.

Exceptionally hard films whose resistance, instead of decreasing, increases slightly with time, were obtained by using four times the amount of sodium hydroxide specified in the Brashear method of depositing silver films.

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[1] Abstract of the following papers: The scientific work of the present Amundsen Arctic Expedition, read before the Meteorological Section of the American Association for the Advancement of Science, Toronto, Canada, December 28, 1921, and before the Philosophical Society of Washington, March 11, 1922; Plans for the scientific work on Captain Amundsen's Arctic Expedition, read before the Physics Club of the U. S. Bureau of Standards, Washington, D. C., February 20, 1922.

ARCHÆOLOGY.

Morley, Sylvanus G., Santa Fé, New Mexico. *Associate in American Archæology.* (For previous reports see Year Books Nos. 13–20.)

The members of the Central American Expedition for 1922 were Messrs. Morley, Guthe, Lothrop, Ricketson, Jessup, and Sopeña; Messrs. Cook, Loomis and Martin, of the Bureau of Plant Industry, United States Department of Agriculture, also accompanied the party on the first trip into Peten during the last half of March and early April.

Owing to the increasing personnel of the Central American expedition and to the extension of its activities, it has become impracticable for all members to take the field at the same time. Doctors Morley and Lothrop sailed from New Orleans for Puerto Barrios, Guatemala, on January 14; Dr. Guthe and Messrs. Ricketson, Jessup, and Sopeña sailed from New Orleans for Belize, British Honduras, on January 28; and Messrs. Cook, Loomis, and Martin for the same destination on February 25.

The activities of the current field-season may be described under four main headings, as follows:

1. A further exploration of the east coast of Yucatan, notably of the ruins of Tuluum, by Doctors Morley and Lothrop (third season).
2. A continuation of Doctor Morley's explorations in northern Peten in search of new archæological sites and hieroglyphic inscriptions (sixth season).
3. An investigation of the agricultural possibilities of the northern Peten region by Mr. O. F. Cook.
4. A continuation of Doctor Guthe's excavations at Tayasal, the last Maya stronghold on the shores of Lake Peten Itza (second season).

After the usual preliminary trip to Guatemala City, to arrange for the continuation of the Institution's investigations in the Department of Peten under the permit granted by the Government of Guatemala in June 1920, Doctors Morley and Lothrop returned to Belize, where they were met by Messrs. Ricketson and Sopeña. A small schooner, with auxiliary gasoline engine, the *Esperanza*, was chartered and on February 7 the expedition sailed for the ruins of Tuluum on the east coast of Yucatan, Mexico. A stop was first made at Payo Obispo, Quintana Roo, to secure the necessary permits from the local authorities, and here Señor Miguel Carral joined the party as the official representative of the Ministry of Fomento.

This trip lasted from February 7 to March 6, during which time two new sites, Tancar and Xelha,[1] were discovered, mapped, photographed, and described, and a more extensive study was undertaken at the ruins of Tuluum.

At Tancar, 4 miles north of Tuluum and 0.25 mile back from the beach, there are two principal plazas and about a dozen stone buildings. At the southern end of the site is a cave with rock carvings, a roughly carved, stone slab leaning against the back wall, and a small square altar of stone and stucco.

Xelha lies some 15 miles north of Tuluum and a mile inland from the sea. The lagoon of the same name extends perhaps half a mile back from the sea, and bifurcates at its inner end. The point of land lying between these two reaches of the lagoon has a narrow neck, where it joins the mainland and this had been fortified by a well-laid stone wall, 150 feet long, 25 feet thick, and 10 to 12 feet high, pierced by a single offset passageway, the whole construction constituting an admirable defense against an attack by land. Half a mile back from the end of this lagoon lies the main group of ruins, centering around a single plaza 315 feet long by 75 feet wide. There are ten or twelve stone buildings, the principal temple being in an excellent state of preservation, with the original sapote beams of the door-lintel still in position.

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[1] Both of these names are probably of ancient origin. John Lloyd Stephens speaks of Tancar as early as 1841 (see Incidents of Travel in Yucatan, vol. II) and Oviedo mentions a point on the east coast of the peninsula named Xelha three centuries earlier.

A fortnight was spent at the ruins of Tuluum, easily the largest site on the east coast of Yucatan, where sufficient data were collected to complete the material for a preliminary report; Doctor Morley first visited this site in 1913, again with Doctors Gann and Lothrop in 1916,[1] and with Doctor Gann and Mr. Held in 1918.[2]

This year a much more extensive investigation was possible. The forest was felled completely inside the inner inclosure and around all the principal temples. Doctor Lothrop made a number of tracings of the mural paintings, especially in Temple 16, as well as extensive architectural and stylistic notes. Mr. Ricketson, assisted by Mr. Alfred Harvey, resurveyed the city, correcting and amending the map made by Doctors Morley and Lothrop in 1916. Individual plans and elevations of all constructions within the great wall were also made, and more than 200 photographs were secured by Mr. Sopeña.

The most important contributions made this year at Tuluum were:

1. The discovery that the principal temples of the city, save only those within the inner inclosure (the Castillo Group) and the so-called Guard House by the East Gate of the North Wall, are distributed along a single main thoroughfare running the entire length of the city from the West Gate in the North Wall to the West Gate in the South Wall. This is a unique feature in the assemblage of Maya structures, the regular practice being arrangement around a single plaza, or groups of connected plazas.

2. The discovery of three new stelæ, two of which are carved, the third being covered with stucco and then painted a brilliant light blue. Stelæ 2 and 3 (carved) are very similar stylistically to the late stelæ at Mayapan, notably to Stelae 8[3] and 9. All four of these stelæ are surrounded with borders of the same kind, i. e., squares with central dots; and Stela 2 at Tuluum like Stela 9 at Mayapan, has an Ahau sign as the only glyph upon it. The best decipherment indicates that this monument dates from some Katun 2 Ahau. Any given katun-ending recurred every 256 years, though on stylistic grounds only the last three occurrences of this katun need be considered here: 1004 A. D., 1261 A. D., and 1517 A. D. Of these, the last (1517) appears most probable to Dr. Morley, although the second (1261) is by no means an unlikely date for this stela. The first (1004) is almost certainly too early. Only one piece of Stela 3, the top, was recovered; this was built into the western pier of Structure 33 (a small altar) in ancient times.

All of the archæological evidence—the architecture, the mural paintings the stucco ornamentations, the serpent columns, the Mayapan type of stela, everything, indeed, save only the comparatively early Stela 1 (10.6.10.0.0. (?) approximately 699 A. D.)—points to Tuluum as having reached its zenith after 1400 A. D., and it should not be forgotten that it was occupied as late as 1518, when Juan de Grijalva made the first voyage down the east coast of Yucatan.[4]

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[1] See Year Book No. 15, pp. 337–339, and The American Museum Journal, March 1917, vol. XVII, No. 3, pp. 191–204.

[2] See Year Book No. 17, pp. 274–275.

[3] See Carnegie Inst. Wash. Pub. No. 219, pp. 574, 575; also Year Book No. 17, second table on p. 274.

[4] Recueil de Pièces Relatives à la Conquête du Mexique, Voyages, Relations, et Mémoires originaux pour servir à l'histoire de la découverte de l'Amérique, vol. x., p. 11, H. Ternaux-Compans.

On March 13 the expedition again left Belize by motor-boat for El Cayo, at the head of navigation on the Belize River, and on March 18 set out from El Cayo for northern Peten with a pack-train of 42 mules and horses. The personnel on this trip consisted of Doctors Morley and Lothrop, Messrs. Ricketson, Sopeña, and Harvey, Messrs. Cook, Loomis, and Martin of the United States Department of Agriculture, and Mr. A. M. Adams, whose services as transport manager had been placed at the disposition of the expedition by Mr. James Craik, of Belize, the local manager of the Chicle Development Company.[1]

This trip lasted a month, during which the ruins of Naranjo, Nakum, Uaxactun, Tikal, Uolantun, Tayasal, Ixlu, and Chichantun[2] (a new site of Class 4), were visited, the party returning to El Cayo on April 11.

On April 14, Messrs. Ricketson and Harvey revisited the ruins of Naranjo, where they made a surveyed map of that site, returning to El Cayo again and thence to Belize early in May. The only previous map of Naranjo had been that made in 1904, by its discoverer, Mr. Teobert Maler, which was inaccurate and incomplete. The new map shows Naranjo as considerably larger than appears from Maler's map—indeed, when considered with its 36 sculptured stelæ and its Hieroglyphic Stairway, it may well be regarded as one of the largest cities of the Old Empire.

On April 18, Doctor Morley and Mr. Sopeña left El Cayo for a month's trip across the northeastern corner of the Department of Peten, penetrating to within 5 miles of the Mexican boundary at a point almost due north of Flores. Two new sites were discovered: Xmakabatun[3] (a city of Class 3) with 4 sculptured stelæ and 7 plain ones, and Naachtun[4] (a city of Class 2) with 11 sculptured stelæ and 7 plain ones; the party returned to El Cayo on May 14 and to Belize on May 18.

The new material discovered during the course of these several trips in northeastern Peten may be briefly summarized as follows:

1. Three new sites (1) Naachtun, 5 miles south of the northern boundary of Peten and almost due north of Flores; (2) Xmakabatun, 35 miles north of El Cayo and just west of the eastern boundary of Peten; (3) Chichantun, at El Gallo, on the *camino real* from Plancha de Piedra to Flores, eastern central Peten.
2. Fourteen new Initial Series.
3. Thirty-one new monuments.
4. Nineteen newly deciphered dates, including all but one of the Initial Series under No. 2.

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[1] The president of this corporation, Mr. M. D. Bromberg of New York, has taken an active interest in Doctor Morley's investigations in Peten, offering all the facilities of the company's large field organization, camps, supplies, mule-trains, and credits, thus contributing largely to the successful exploration of this remote region.

[2] *Chichantun:* "Small stone"; *chichan,* "small" and *tun* "stone." This name was given to this new Class 4 site because the two sculptured stelæ found here were very small, not more than 4 feet high.

[3] *Xmakabatun:* "Stone without a name"; *xmakaba,* "without a name" and *tun,* "stone." This name was given to this new Class 3 site because of the fact that two of its four sculptured monuments (Stelæ 3 and 4) had no hieroglyphs at all inscribed upon them, and the other two (Stelæ 1 and 2) showed only the faintest traces of them.

[4] *Naachtun:* "Distant stone"; *naach,* "distant" or "far off" and *tun,* "stone." This name was given to the new Class 2 site found this year because of its extreme remoteness, being at the very center of the Yucatan Peninsula, far removed from every point of approach.

The fourteen new Initial Series are:

Site.	Monument.	Maya date.	Christian era.
Uaxactun.........	Stela 18	8.16. 0.0.0	97 A. D.
Uaxactun.........	Stela 19	8.16. 0.0.0	97 A. D.
Naachtun.........	Stela 1	9. 9.10.0.0	364 A. D.
Naachtun.........	Stela 2	9.10.10.0.0	383 A. D.
Naachtun.........	Stela 3	9. 5. 0.0.0	275 A. D.
Naachtun.........	Stela 4	Undeciphered.	....
Naachtun.........	Stela 5	9. 6.10.0.0 (??)	304 A. D.
Naachtun.........	Stela 7	9.17. 0.0.0 (??)	511 A. D.
Naachtun.........	Stela 8	9.16. 0.0.0	492 A. D.
Naachtun.........	Stela 9	9.15. 0.0.0 (?)	472 A. D.
Naachtun.........	Stela 10	9.16.10.0.0 (?)	502 A. D.
Quirigua..........	Stela T	9.14. ?.?.? (?)	452 A. D.
Quirigua..........	Stela U	9. 2. ?.8.0 (?)	216–235 A. D.
El Encanto.......	Stela 1	9. 8. ?.9.? (?)	334–354 A. D.

The most important results of Doctor Morley's explorations this season center around the highly significant new stelæ found at Uaxactun, and the discovery of so large a new city as Naachtun. The ruins of Uaxactun were discovered in 1916 by the Institution's Central American Expedition. At that time this site was unique in having the first and only Baktun 8 Initial Series monument then known, namely, Stela 9, recording the date 8.14.10.13.15, approximately 68 A. D.[1] Last year another Baktun 8 Initial Series monument was discovered at a new site, Uoluntun, 12 miles south of Uaxactun, recording the date 8.18.13.5.11, approximately 150 A. D.[2]

This year no less than four more Baktun 8 dates were deciphered at Uaxactun, three of them on new monuments: Stelæ 17, 18, and 19, and the fourth on Stela 4, discovered in 1916:

Site.	Monument.	Maya date.	Christian era.
Uaxactun.........	Stela 18	8.16.0.0.0	97 A. D.
Uaxactun.........	Stela 19	8.16.0.0.0	97 A. D.
Uaxactun.........	Stela 4	8.18.0.0.0	137 A. D.
Uaxactun.........	Stela 17	8.19.0.0.0	157 A. D.

The first two, Stelæ 18 and 19, stand in front of the same temple and record exactly the same day, an Initial Series in each case, the coefficients being expressed by simple bar and dot numerals (see *A* and *B*, figure 1), and their decipherment is correspondingly certain. This date is less than 29 years later than the date on Stela 9 at this site, and these two stelæ, therefore, become the second and third earliest monuments yet found in the Maya area. They also corroborate the reading suggested for Stela 9 six years ago. Although the dates on Stelæ 4 and 17 are recorded as Period Endings, both are reasonably certain, particularly that on Stela 4, which shows quite clearly "8 Zotz" followed by an Ending-sign. This can hardly be other than 8.18.0.0.0 12 Ahau 8 Zotz, as suggested above.

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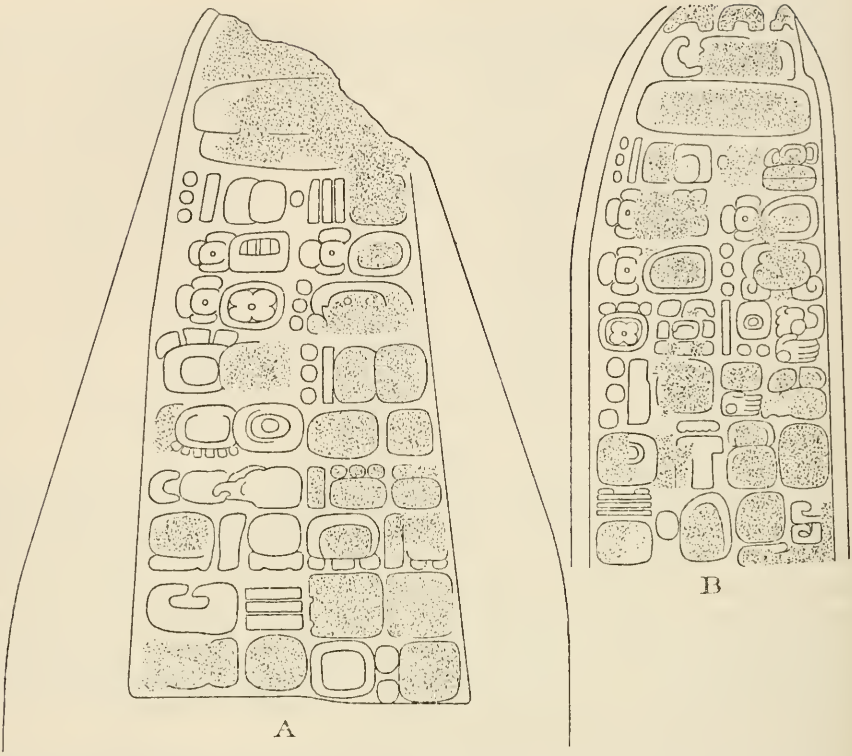
[1] See Year Book No. 15, pp. 339, 340.

[2] See Year Book No. 20, pp. 361.



A, Stela 19, and B, Stela 18 at Uaxactun. These two stelæ record the same date: 8.16.0.0.0 approx. 150 A. D. Next to Stela 9 at this same site they are the two earliest Maya monuments known.

Another important new early monument discovered at Uaxactun this year is Stela 20, probably dating from 9.3.0.0.0 (235 A. D.), also recorded as a Period Ending. The front is carved with an heroic-sized human figure, front view, carrying a ceremonial bar in the arms, the presentation being almost identical with that on Stela 7 at Copan, for example, so close, in fact, that the sculptors of these two widely separated monuments must have had a common source of inspiration, a striking example of the homogeneity of Old Empire culture even at this early date.

Another important monument found this year was the fragment of a very early stela which had been worked down into a round altar in ancient times and re-used as such with Stela 9. Unfortunately, it was impossible to date this fragment exactly, but stylistically it would seem to have been at least as early as Stela 9, itself the earliest Maya Stela known, if not indeed earlier.

The number of these early stelæ at Uaxactun, coupled with the fact that the next earliest stela elsewhere is nearly a century and a half later (Stela 9 at Tikal, 9.2.0.0.0, 216 A. D.),[1] strongly indicates the advisability of further intensive investigation, including excavation at this site. No other site now known would probably shed more light upon the beginnings of the Old Empire

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[1] Uoluntun is an exception to this statement, but it is so small, having only a single pyramid and a single monument, that it has been disregarded in this connection.

(certainly so far as the Peten region is concerned) than Uaxactun, where all the earliest surely deciphered monuments have been found.

The geographic location of this site is also significant. It became apparent from this year's explorations that Uaxactun is located at the head of the Ixcan[1] Valley, in that mountain cluster which is precisely the very backbone of the Yucatan Peninsula, the waters of the Ixcan River finding their way out through the Hondo River into Chetemal Bay and thence into the Caribbean Sea, on the east side of the peninsula. Northwest of Uaxactun 8 or 10 miles is the main divide of the peninsula, streams rising on the far side of this range, such as the Paixban River for example, flow out through the San Pedro Martir and San Pedro Candalaria Rivers into the Gulf of Mexico, while to the south are ranges beyond which lies the great interior drainage basin of which Lake Peten Itza is the largest member.

Uaxactun is thus located at the geographical as well as the topographical center of the Old Empire region, the central point from which distribution subsequently took place to other regions, judging from the pronounced chronological priority of the Uaxactun dates.

Another factor contributing to the scientific importance of this site is its length of occupation (561 years), more than a century and a half longer than any other Old Empire city on the basis of the dated remains.

During the present field season two very late Old Empire monuments were also found here, their dates being recorded as Period Endings:

Uaxactun..........	Stela 13	10.0.0.0.0	571 A. D.
Uaxactun..........	Stela 12	10.3.0.0.0	630 A. D.

The former is the first monument yet discovered, dating from the closing day of Baktun 10. The previous katun-ending, 9.19.0.0.0, had been found recorded on four monuments at three different sites, as, for example, here at Uaxactun on Stela 7, at Naranjo on Stelæ 7 and 10, and at Quirigua on Temple 1; and the succeeding katun-ending, 10.1.0.0.0, appears on eight monuments at five different sites: Benque Viejo, Stela 1; Flores, Stela 2; Ucanal, Stela 3; Nakum, Stela D; and Seibal, Stelæ 8, 9, 10 and 11, but no monument had been found previously dating from 10.0.0.0.0 until the discovery of Stela 13 at Uaxactun in April of this year.

The other Baktun 10 monument found this season (Stela 12) is of even greater importance. This records the date 10.3.0.0.0., which makes it of exactly the same age as Stela 10 at Xultun, discovered by the expedition of 1920,[2] and together they have the unique distinction of being the two latest Old Empire monuments known anywhere.

Priority of origin, length of occupation, lateness of abandonment, centrality of location, all combine to make Uaxactun the most promising of all Old Empire sites for intensive operations.

Naachtun, the large new site discovered on May 3 of this year, is interesting chiefly because of its location, being the northernmost city of the Old Empire yet reported. It is on a low bench of hills toward the head and on the southern side of the Paixban Valley, the streams of which flow into the San Pedro Candalaria River; it thus lies northwest of the ranges forming the main watershed of the Yucatan Peninsula. The long axis of the city extends for about half a mile east and west; there are two principal plazas and a score or more of subsidiary ones. The buildings are now mostly fallen, destroyed by the luxuriant forest growth, though here and there a wall is standing, mute witness to former magnificence.

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[1] In Doctor Morley's report for last year it is stated that Uaxactun lies at the head of the Holmul Valley (Year Book No. 20, p. 362). Closer exploration this year established the fact that this site lies just north of the low divide between the Ixcan and Holmul Valleys, and that it is therefore at the head of the Ixcan Valley instead.

[2] See Year Book No. 19, pp. 322, 323.

An analysis of its inscriptions shows Naachtun was not as old as Uaxactun by more than two centuries, nor survived it as late by more than a century. Its art and architecture, in spite of its size, are provincial, probably because it was a frontier city, and its sculptures are not to be compared with those of Piedras Negras and Quirigua, though both the latter sites have fewer structures and cover less area. The earliest date deciphered is 9.5.0.0.0 (275 A. D.) on Stela 3, and the latest, some time during Katun 17 (511–531 A. D.) on Stela 7. Judging by the provenance of the dated monuments, the Eastern Plaza was built during the Early Period and the Western Plaza during the Great Period, with no monuments thus far found dating from the Middle Period.[1] Naachtun is an excellent example of a large provincial Old Empire city of mediocre esthetic achievement.

A few scattering new inscriptions should be noted here. Mr. R. D. Martin, of the U. S. Department of Agriculture, discovered a new monument at Naranjo, to which the name Stela 36 was given. This bears the Calendar Round date 12 Ahau 8 Pax, which corresponds to the Initial Series 9.17.10.0.0. (521 A. D.). There is a band of four glyphs across the top of the stela, the rest of the front, the back, and sides being plain. It would almost appear as though this monument had been left in an unfinished state.

At the conclusion of his explorations in Peten in May, before returning to the United States, Doctor Morley spent two days at Quirigua, Guatemala, where two new stelæ had been found on the summit of a hill 2 miles west of the principal group.

These monuments, which were named Stelæ T and U respectively, proved of exceptional interest, and one of them, Stela U, offers several perplexing problems. It has only four period-glyphs between the Initial Series introducing-glyph and the day-sign, and it is therefore evident that one of the period-glyphs has been omitted, probably the kin-sign.[2] The best reading for the Initial Series is 9.2.?.8.0, which in itself raises another problem. If Stela U really dates from Katun 2 as this reading would indicate, it would make it more than two and a half centuries earlier than the next earliest monument here at Quirigua, an improbable situation. On the other hand, there are no Secondary Series on the monument to bring it down to the period of the other Quirigua stelæ.

The other new Quirigua monument, Stela T, dates from some time in Katun 14, and because of its close stylistic similarities with Stela U, it seems not improbable that this latter monument also dates from the same katun, though this fact has not yet been established from its inscription.

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[1] Stela 2 really dates from the first decade of the Middle Period (9.10.10.0.0), but from its provenance it is evident that it was associated with an Early Period building.

[2] The day-sign of the Initial Series terminal date is surely Ahau, indicating that the kin coefficient was zero, and as such could therefore be omitted without sacrifice of clarity. See "An Introduction to the Study of the Maya Hieroglyphs," Bull. No. 57, Bur. Amer. Eth., S. G. Morley, pp. 127, 128, and "The Inscriptions at Copan," Carnegie Inst. Wash. Pub. No. 219, pp. 203, 301.

Mr. O. F. Cook's study of the agricultural possibilities of the Peten region developed nothing in the way of the former use of agricultural terraces like those he found in Peru or in the Cahabon District of southern Guatemala, nor do the natural conditions indicate that the land was kept in permanent cultivation.

In a preliminary announcement Mr. Cook states:

> "The milpa system of agriculture, the planting of maize and other crops in temporary clearings, probably was used by the ancient inhabitants of Peten, as it still is by the modern representatives of the Mayas in the neighboring regions of Central America.
>
> "The milpa system has a natural limit when the land becomes occupied by grasses, since the burning over of grasslands does not kill the roots or allow crops to be planted. In the absence of plows or metal tools for the tillage of grass lands, primitive people generally were limited to the destructive, bushburning, milpa agriculture. But in view of the long occupation of the ancient sites in Peten, it is believed that precautions must have been taken to keep the milpa fires from spreading to adjacent lands, a custom still followed in the Cahabon district, south of Peten. By confining the fires to the milpas the fallow lands are kept in bush, and the complete deforestation and reduction of the country to a grass land, or savannah, are deferred. Nevertheless, a gradual extension of savannahs is to be expected in any populous region that is farmed continuously by the milpa system, so that in time the planting of corn or other crops is restricted and the population declines or moves to new lands, as the Mayas appear to have done when the cities of Peten were abandoned and new cities were built in Yucatan, in the sixth century A. D.[1]"

Extensive artificial terracing has been found recently in the hilly country of western British Honduras, in the Cayo District, south of the Belize River. All the archæological evidence here, however, pottery, mounds, etc., indicates that the region was occupied very much later than the lowlands of Peten just west of it; that whereas the cities of the latter date from the Old Empire (down to 630 A.D.), the sites of the Cayo District are probably to be assigned to the very close of the new Empire, possibly as late as the fifteenth and sixteenth centuries.

It is suggested that this region may have been colonized from the highlands of Guatemala by groups of the southern Maya, the Kekchí, for example, who still have villages as far north as San Antonio in southwestern British Honduras and San Luis and Poctun in southeastern Peten. The southern Maya probably developed the use of agricultural terraces after the abandonment of the Peten region and their migration southward into the mountain valleys of Guatemala (after 630 A. D.), so that the discovery of such terraces in the Cayo District may point to their southern origin, and thus corroborates rather than vitiates Mr. Cook's conclusions as to their non-existence during the Old Empire in Peten.

Further study of these terraces as well as of the archæology of the Cayo District will be necessary before final conclusions may be formulated, but it already seems fairly evident that its occupation dates from a time long subsequent to the Old Empire period, and that its colonization possibly may not have taken place until after the thirteenth century.

On August 5, Doctor Morley sailed for Rio de Janeiro, where he represented the Institution at the Twentieth International Congress of Americanists held there August 20-30.

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[1] The Official Record, United States Department of Agriculture, vol. 1, No. 20, May 17, 1922, pp. 1, 3.

Dr. Guthe resigned from the Institution on August 1 to accept a position with the University of Michigan; his report on the current season's work at Tayasal follows.

Report of Carl E. Guthe.

Through the cordial support of General Isidro Valdez, who was governor of the Department of Peten when Doctor Guthe arrived, it was possible to begin work at Tayasal with twelve laborers on February 20. Don Bernardo Burmester, the government interventor, by his interest and cooperation, also did much to facilitate the progress of the excavations. The entire season was devoted to a study of the construction of the long mound, the eastern end of which had been cleared during the previous season.[1] During the course of the work six trenches were run, four on the northern or plaza side of the mound, and two on the southern side. The eastern and western ends of the structure were definitely located. Toward the eastern end a trench was dug entirely through the mound, exposing a complete cross-section and disclosing, under the late construction, the remains of an earlier building of the Old Empire. This earlier building was placed directly upon the rock of the peninsula, which at this point slopes rather abruptly from south to north.

The excavations this season disclosed that this structure consisted of a platform raised about 1.5 meters above the plaza level, with two stairways built into the wall. Upon this platform there probably was an early building which was later razed to within one course of the platform, over which was placed a second platform, with a bench at the southern side.

The city of which this early structure formed a part was probably abandoned early in the seventh century A. D., i. e., the period of abandonment of the Old Empire Peten sites. For at least seven and possibly eight centuries this city was uninhabited. During this time a thick deposit of earth and stone accumulated south of the bench. Why no traces of a similar deposit north of the bench are found in this part of the mound is a mystery.

The settlers of the New Empire raised a high terraced substructure on this site, the retaining walls of which were built upon the ruins of the older building.

The unusually thin layer of débris upon the upper floor of this mound and the almost total absence of large stones lead to the conclusion that the building itself was of wood and palm-leaf thatch. At the western end, however, a fragment of a dressed stone wall was found at the northern edge of this upper floor.

Just to the south of the mound a skeleton was found. The individual had been buried in a flexed posture, on his back, with the shoulder-girdle considerably above the pelvis. This burial should be associated with the later period, for it rested upon the early floor, less than a meter below the upper or late floor. No furniture was found with it. No trace of a skull, teeth, or of the atlas and axis could be found. It is assumed that the individual was decapitated before burial, a procedure which Villagutierre states existed at Tayasal.

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[1] See Year Book, No. 20, p. 367.

During Doctor Morley's visit to Flores, a large stone, found in the center of Mound 1, excavated last year, was raised. It proved to be a badly weathered Old Empire stela. The front of it portrayed a figure kneeling upon a large mask panel. Villagutierre, in describing the Tayasal of Ursua's time, probably refers to this building and monument when he speaks of "the temple of the plaza" with a "horrible figure."

The minor antiquities were as noticeable by their absence as last year. A stone hennequen pounder and a miniature greenstone ax were among the objects found. Several pottery heads were also turned in by the workmen. Some of them were clearly pure Maya in technique. Others bore strong resemblance to both the Teotihuacan and Aztec heads.

The débris is filled with broken pottery. The coarser, heavier pieces of the later type are usually found near the surface. Many are beautifully polished and some show traces of paint. But the finer, thinner sherds were usually found associated with the earlier construction. Often the designs could still be traced, occasionally showing glyph cartouches. On a very few sherds the designs were incised.

Van Deman, Esther B., Rome, Italy. *Associate in Roman Archæology.* (For previous reports see Year Books Nos. 9–15, 20.)

Work was resumed in Rome in the latter part of April. While conditions were found in general very favorable, changes in the administration of the several offices in charge of the monuments and excavations caused some confusion and delay. Little material of value for the special work in hand has been brought to light during the past five years in the Forum and Palatine. Several important monuments, however, have been uncovered elsewhere, especially an early basilica, for the dating of which an early study of the construction is highly desirable.

A careful survey was made of the various groups of remains of which, as stated in the last report, it has been deemed advisable to publish a preliminary discussion. Urgent requests have come for the immediate publication of the data so far compiled of a number of the more important monuments. The rapid disintegration of the earlier walls in the Forum and along the Sacra Via, through long exposure to the weather since their excavation, with the consequent loss of much of the most valuable evidence concerning their history and construction, has, however, rendered it imperative to confine the work for the year to this region. The evidence for the rebuilding of the Forum and several of its more important monuments at a higher level by Sulla has been found even more conclusive than had been hoped for. A corresponding change in the level of the Sacra Via is now clear, accompanied by the restoration of many of the buildings along its course. To the six imperial periods previously recognized in the remains in this region, a seventh has been added.

For a number of years the advisability of an exhaustive chemical and microscopic examination of the Roman bricks and mortar of the different periods has been deeply felt, as a means of determining the provenience of the materials used in their composition and an aid to their classification. The realization of this desire has been at length rendered possible by the generous offer of assistance by Dr. Henry S. Washington, of the Geophysical Laboratory, whose earlier work in the archæological field renders him especially fitted for the task. The months of June and early July were largely devoted to a review of the whole field from this standpoint and the choice of the materials necessary for this investigation. It is hoped that, in connection with his valuable work on the volcanic stones of the region, Dr. Washington, in association with Dr. Tenney Frank, Professor of Latin in Johns Hopkins University, may be able to make also a study of the stones used in the greater Roman monuments.

A valuable series of experiments has been undertaken during the year by Professor Alfred H. White, head of the Department of Chemical Engineering of the University of Michigan, to determine the water absorption of the Roman bricks and the changes in volume of the mortar of the different periods. The results of this investigation, while primarily of interest to modern engineers, will, it is hoped, furnish additional data for the classification of these materials.

An alarming change has taken place, in the last decade, in the condition of the monuments of most importance for the study of Roman construction as well as Roman history. Many of these monuments are at present threatened with complete extinction or such extensive restoration as to render them almost valueless for study. While this is most noticeable in the earlier monuments, especially those made of the more friable tufas, many of the imperial walls must be very shortly restored to prevent entire collapse. The scientific investigation and publication of these remains as rapidly as possible is imperative before newer excavations are undertaken.

BIBLIOGRAPHY.

Garrison, Fielding H., Army Medical Museum, Washington, District of Columbia. *Preparation and publication of the Index Medicus.* (For previous reports see Year Books Nos. 2–20.)

The Index Medicus for 1921 (third series, Volume I) contains 1,126 pages, with an author's index covering 116 pages, as compared with the volume of 932 pages, with an index covering 175 pages, for 1920. This shows an increase of 194 pages of subject-matter over the volume for 1920, in spite of the actual space gained through the strictly alphabetical arrangement of the new series. This increase in size is due largely to the remarkable increase in the European medical literature in countries which are gradually recovering from the effects of the war, one feature of this phenomenon being the appearance of a large number of new periodicals devoted to medicine and the biological sciences. The arrangement of the Index Medicus by subject headings in strictly alphabetical order is a new departure, but no difficulty has been experienced by the editors in making this change, since the new arrangement is exactly that employed in the *Index Catalogue* in the Surgeon General's Library since 1880. It has been found, however, that certain titles which, in the *Index Catalogue,* would be given a definite place in an alphabetical sequence have been found to serve a better purpose if included under the more general divisions of medicine to which they are related, protected by the usual cross-references. Beginning with 1922, therefore, the table of contents printed at the beginning of each number of the journal gives a complete picture—or bird's-eye view—of the relation of special titles of importance to the larger subdivisions to which they are related and under which they would have been included in the earlier arrangement. Thus, under otology, in the table of contents, a specialist in diseases of the ear is referred to "Audition," "Auditory canal," "Deafmutes," "Deafness," "Ear," "Mastoid process," "Nystagmus," "Oto-rhino-laryngology," "Sea sickness," and "Vertigo (Labyrinthine)," as collateral subjects which must be consulted in the alphabetical sequence, if he wishes to cover the literature of the quarter in which he may be interested. Each quarterly number includes the entire literature of the three months preceding the dates specified on the title page of the individual number of the journal, that in the January number, 1921, for instance, covering the literature for October, November, and December 1920. The new arrangement, in effect, affords a miniature *Index Catalogue* of the literature of medicine for any given quarter of the year. The author index will furnish an alphabetical key to all the authors represented in the four numbers.

Beginning July 1, 1922, the Index Medicus will be under the editorial supervision of Major Arthur N. Tasker, Medical Corps, U. S. Army, with Dr. Albert Allemann as associate editor.

BIOLOGY.

Castle, W. E., Harvard University, Cambridge, Massachusetts. *Continuation of experimental studies of heredity in small mammals.* (For previous reports see Year Books Nos. 3–20.)

During the past year further progress has been made in the study of the linkage relations of genes in mice, rats, and rabbits. No new linkages have been discovered, but more precise values have been found for those already reported and the relative frequency of crossing-over in the two sexes has been more fully investigated.

In mice the linkage relations of seven genes have been investigated, two of which are linked, being located, as we suppose, in the same chromosome. The seven genes are (1) agouti, (2) albinism, (3) pink-eye, (4) chocolate, (5) dilution, (6) piebald, and (7) black-eyed-white. The two genes which are linked are albinism and pink-eye and the cross-over percentage between them is for male parents 13.7 ± 0.4, and for female parents 16 ± 0.6. The numbers of young on which these averages are based are males 7,007, females 3,345, numbers large enough to make the probable errors very small. Accordingly, it may be regarded as certain that in mice crossing-over occurs a little more freely in oögenesis than in spermatogenesis. The same thing is found to be true in rats.

In the case of rats (*Mus norvegicus*), the linkage relations of five genes have been studied, viz, (1) agouti, (2) albinism (and its allelomorphs), (3) pink-eyed yellow, (4) red-eyed yellow, and (5) hooded pattern. Of these five genes, three are found in one linkage system, presumably lying in one and the same chromosome. They are albinism and the two kinds of yellow. Albinism is very closely linked with red-eyed yellow, but neither of them is linked anything like as closely with pink-eyed yellow. In all cases the cross-over percentage is higher for female parents (i. e., in oögenesis) than for male parents (spermatogenesis), as the following figures show.

Genes.	Cross-over percentage, male parents.	No. of young.	Cross-over percentage, female parents.	No. of young.
Albinism and red-eyed yellow	0.18 ± 0.35	8,828	0.35 ± 0.55	3,759
Albinism and pink-eyed yellow	18.4 ± 0.2	21,255	21.9 ± 0.3	11,480
Pink-eyed yellow and red-eyed yellow	15.5 ± 0.7	2,063	20.4 ± 0.6	2,683

The order of the three genes, on the linear arrangement theory, is evidently (1) albinism, (2) red-eye, (3) pink-eye. The total "map-distance" would be for females 21.9, for males 18.4, a complication not encountered in *Drosophila*, where only female parents give cross-overs.

In rabbits the linkage relations of six genes have been rather fully investigated. The investigation of three others is in progress. The six genes on whose linkage relations adequate information is in hand are (1) agouti, (2) albinism (and its several allelomorphs), (3) dilution, (4) yellow, (5) English spotting, and (6) angora (long) hair. Of these, the last two are linked with each other, the cross-over percentage being 16.0 ± 1.7 in the case of male parents (spermatogenesis), an estimate based on 400 young. Female parents in 115 young have given 9 cross-overs, which is 7.8±3.1 per cent. The numbers are as yet insufficient to show conclusively whether females produce more or fewer cross-overs than males. Certain it is, however, that *both sexes* produce cross-overs in all cases of linkage thus far demonstrated in mammals. Since the same is true in plants, it seems to be an exception rather than a rule that has been encountered in *Drosophila,* where crossing-over occurs only in females.

Dr. W. L. Wachter has assisted in the linkage investigations with mice and rats.

Kofoid, Charles A., University of California, Berkeley, California. *Investigation on intestinal protozoa.*

The scientific results attained have been:

1. The discovery of amebæ in bone marrow in arthritis deformans.

2. The discovery of amebæ in lymph glands in Hodgkin's disease.

3. The finding of amebæ in abundance in the capillaries in the margins of intestinal amebic ulcers.

4. Analysis of the process of mitosis and determination of chromosome number in two human intestinal amebæ. This affords a critical morphological basis for the accurate identification of amebæ in human tissues.

5. The morphological analysis of the process of mitosis in giardia enterica from man.

6. A considerable amount of detailed information on a number of human intestinal amebæ and flagellates and amebæ which awaits supplemental material and analysis before publication.

7. The establishment of craigiasis as a human disease with an etiological factor, craigia hominis. This has been denied by English investigators without adequate data.

8. The finding of amebæ in non-healing ulcers of the skin.

9. Critical evidence as to the necessity of repeated examinations for detection of intestinal infections. It has been and is in some quarters the custom to rely upon one examination.

10. The discovery of the prevalence of family infections.

11. The statistical analysis of about 20,000 examinations of over 5,000 persons for intestinal parasites.

For papers published during the past year, see page 25 of the Year Book.

Mann, Albert, Washington, District of Columbia. *Continuation of investigations and preparations for publication of results of work on Diatomaceæ.* (For previous report see Year Books Nos. 18–20.)

To keep this report within its proper limits it will be necessary to give almost exclusive attention to the important trip along the Pacific Coast, made in June to September 1921, a forecast of which was included in my last report. The purposes of this trip appear to have been accomplished, namely, a visit to all the biological stations along the coast and to the principal fossil diatom deposits of California, not so much to carry on research as to consult with the scientists at these places, to awaken more interest in thorough diatom study, and to plan for some cooperation in research work of the various problems involved.

Probably the chief problem is a thorough investigation of the living marine diatom flora, involving interesting and valuable connections with other forms of marine life, especially the edible fishes and shell-fish. La Jolla, Laguna Bay, Pacific Grove, San Francisco and its adjacent waters, Portland, and Puget Sound, were the principal points of interest. The opportunities afforded for collecting material at these places showed that the Pacific diatom flora is rich in species peculiar to those waters and in some instances quite abundant, but less so than that of the Atlantic Coast. This is probably due to the much greater uniformity in water temperature, salinity, depth along the shore, and other qualities of this coast, from Mexico to Canada, than is the case on the Atlantic seaboard. Still more important, the far less frequent and deep indentations of the Pacific coast-line and the much fewer rivers and streams discharging into these, necessarily afford a much narrower range of biological conditions, which in turn must affect proportionally the range in diversity of aquatic life. There seems to be, therefore, a simpler problem in working out the relationships of marine ecology on the Pacific than on the Atlantic Coast.

The three places promising the richest results of study were found to be Pacific Grove on Monterey Bay, San Francisco (with its enormous area of ocean and bays), and Puget Sound. The time of making this trip, though on the whole well selected, was unfortunate in the absence of a good many of the biological workers on vacation; some of the places, notably Friday Harbor on Puget Sound, were closed for the season. But the Puget Sound station at Nanaimo, British Columbia, was fortunately still open—a place of unusual resources for marine biological research.

The cooperation offered everywhere was so spontaneous that great progress in thorough diatom study is sure to result. In fact, the steady inflow of collected material sent to Washington is a proof of this. This cooperative plan of Pacific coast diatom study includes sending to the Washington laboratory, samples taken at regular intervals at the various points on the coast. These will form a central collection of consecutive samples that will be of much future value to science. Parts of each sample are to be retained at each locality and investigated by the local workers wherever practicable; otherwise, the work will be attempted at the Washington laboratory, and in all cases help in identifying difficult forms will be given. When this cooperative work has supplied its information on the kind and quantity of the diatom flora at the various places and under different conditions of time, depth, etc., an important factor in the big problem of the Pacific coast fish-food supply will have been secured.

Less time was given to the fossil diatom deposits; and yet notable results were obtained. Several days were spent at the large and important deposit at Lompoc, California; and subsequently a complete series of samples of the 1,400 foot (or more) depth of strata comprising this great bed has been shipped to Washington and is already prepared for study. The samples were taken at intervals of 25 feet or less, and probably represent the most important series of fossil diatom stratification in existence. Their geological interpretation promises to be valuable.

An almost equally complete set of samples has been secured in the vicinity of Los Angeles, where diatom outcroppings are abundant and remarkably diversified. Material of this kind was also collected at Monterey Bay and in the neighborhood of San Francisco, as well as a few samples from Oregon and Washington.

During the trip lectures were given at various points on local diatom conditions, as well as brief instructions and demonstrations of methods for diatom study.

The work at Washington has been handicapped for lack of adequate laboratory help. The study is a peculiar one; the financial reward is necessarily small, and so far it has been impossible to find candidates willing to take the position and gifted with the necessary interest in and talent for this field of scientific research. The writer has therefore had to do most of the work of preparation and study without assistance. The following is a short summary:

The long-delayed report on the diatoms of the Philippine Islands, mentioned in former reports, is now ready for publication. The study of the diatoms of the Canadian Arctic Expedition is about completed. The material of the Antarctic Expedition, sent out from Australia under Sir Douglas Mawson, has been received, cleaned, and prepared for study and largely worked out. It is proving to be very rich in genera and species, some of which are new. As is the case each year, a good many samples of diatom material from private parties, chiefly commercial houses, has been submitted to the laboratory for examination. This public service seems to be justified, although it takes considerable time through the year; it has some scientific value, and the information sought is practically unobtainable outside of this laboratory.

In addition to the work of preparing and investigating diatom material, the large collection of such material located at the U. S. National Museum, together with prepared specimens, has been entirely reclassified during the year on a plan which makes it available for the growing number of outside workers who apply for information or for diatom supplies. Like all new fields of research, the opportunities are much in excess of the facilities, but encouraging progress is being made.

Morgan, T. H., A. H. Sturtevant, and C. B. Bridges, Columbia University, New York. *Study of the constitution of the germ-plasm in relation to heredity.* (For previous reports see Year Books Nos. 15–20.)

In the course of the year about 20 new mutant types have been studied, and at least 10 of these will prove useful for future work on the localization of the genes in the chromosomes. None have fallen outside the four known linkage groups. A new allelomorph at the white locus has been found, which makes 11 mutant genes at the locus, or 12 in all, counting the wild-type gene. The evidence showing that this "nest of genes" is not due to close linkage, but to independent mutation of the same wild-type gene, has been given elsewhere. The significance of this evidence in its bearing on the "presence and absence" hypothesis has not even yet been appreciated by workers in other fields.

In the course of the last two years, the amount of the data bearing on the location of genes in chromosome III has been approximately doubled. This has necessitated the construction of a more complete "map," which is here represented by a partial list of loci, with their distances from an arbitrarily chosen locus at one end. The locations are based on the most usual types of cross-over values; that is, the "distances" are those most likely to be found in a new experiment and are, therefore, those that will best serve as a basis for prediction. The greatly increased knowledge of double crossing-over in this chromosome has enabled us to convert the recombination percentages into map-distances with a higher degree of accuracy than heretofore. From a study of the cases in which double crossing-over occurs, curves have been constructed (fig. 1) that show the correction on account of multiple crossing-over for any two loci on the map. The curves show the difference between recombination percentage and map-distance for any two loci considered. It

Map of Chromosome III of Drosophila melanogaster.   August 30, 1922.*

0.0	roughoid*	47.5	Deformed +	68.5	compressed-dilapidator
10. ±	intensifier of Star	47.8	weazened		
12. ±	dwarf—b	48.0	pink*	69.5	Hairless*
15. ±	smudge.	48.5	compressed	70.7	ebony*
22. ±	lethal—IIIh	49.5	mahogany	72.0	band +
24. ±	divergent	50.7	maroon +	75. ±	CIII
25. ±	benign—III	51.0	dwarf	75.7	cardinal*
26.0	sepia*	52.0	warped +	76.2	white-ocelli +
26.5	hairy*	58.3	Two-bristles	83. ±	lethal—IIIa
36.5	cream—III +	58.5	spineless*	91.1	rough*
39.1	lethal—IIIf	58.7	bithorax +	93.0	crumpled
40.2	tilt +	59. ±	Intensifier of scute	93.8	Beaded
40.4	Dichaete*	59.5	bithorax—b	94.1	Pointed-wing +
40.4 ±	vortex—III	62.0	stripe +	95. ±	Minute—dIII
40.7	lethal—IIIe	63. ±	lethal—IIIi	100.7	claret*
43.5	ascute	63.1	glass +	101.0	Minute +
43.8	scarlet*	64. ±	giant	105. ±	Minute—f
44.0	varnished +	64.0	kidney	106.2	Minute—g*
46.0	curled +	65. ±	spread		
46.5	ski—III +	66.2	Delta*		

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* Dominants are capitalized. The mutants of greatest importance are indicated by *. The mutants of medium value are followed by +.

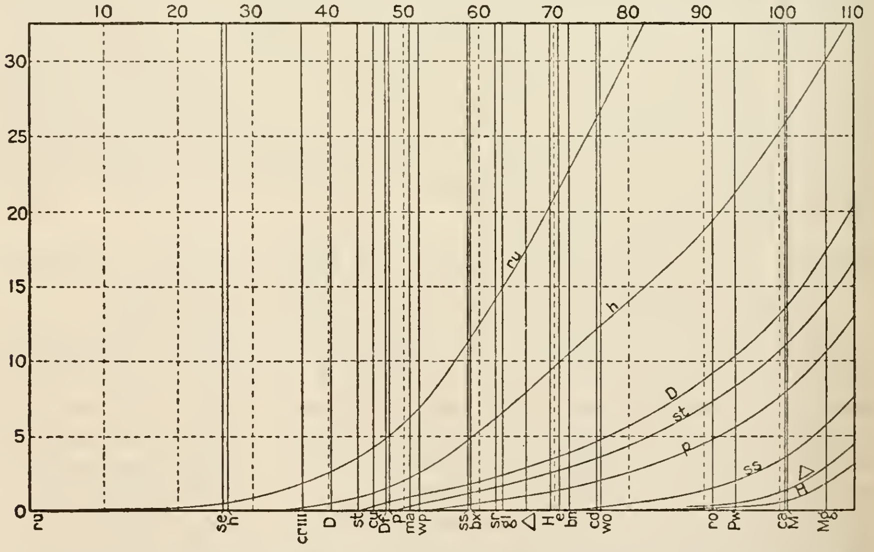

FIG. 1.—Base line of figure is the map of chromosome III, simplified by the omission of all except the more important loci. Each curve shows in the height at which it cuts the ordinate from a given locus the amount by which crossing-over exceeds recombination.

will be observed that these curves are not all alike in shape, that they are specific for the specific regions involved. From this it follows that no general formula can be devised that will convert recombination percentage into map-distance.

The curves of figure 2 show the results of the application of the corrections, shown by the first set of curves, to the map. For each curve of the first series there is a corresponding curve in the second series which gives the recombination percentage corresponding to each pair of loci.

This map enables one to read off at once the expected percentage of recombibination for any two loci in chromosome III, while to use an ordinary map one has to apply a correction on account of multiple crossing-over. Here this correction has been included in the curves. The map-distance can also be read off, if desired, from the straight line that accompanies each curve.

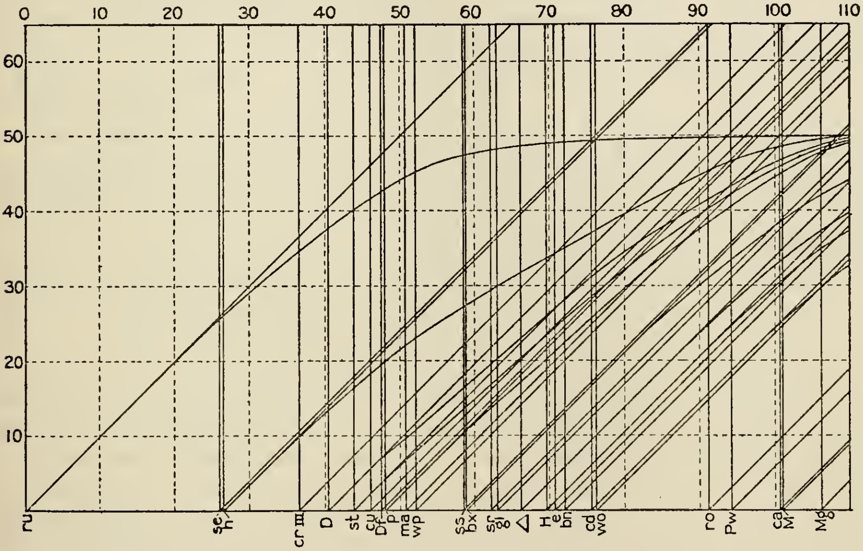

FIG. 2.—Each slanting straight line shows in the height at which it cuts the ordinate from a given locus the amount of crossing-over between that locus and the locus from which the line originates. Similarly, each curve shows the amount of recombination for the locus of origin and any given locus.

The number of mutants has been increasing so fast from year to year that it has become confusing to adhere to the original simple system, or even lack of system, of naming them. We have been forced, therefore, to the uncongenial task of systematizing our nomenclature, but have followed the old lines as closely as possible. These changes are not recorded as final, but only transitional. They serve to simplify the body of facts that has so far accumulated. A full account of the revision is given in our forthcoming monograph on the characters of the third chromosome of *Drosophila*.

In order to construct and perfect the maps of that species most closely similar to *Drosophila melanogaster*, namely *Drosophila simulans*, it has been necessary to find new mutants and to get additional data concerning the loci already known. Since these two species can be crossed, it has been possible to demonstrate that 12 of the *simulans* mutant types are allelomorphic to types already known in *melanogaster*. This makes it possible to be certain that one is dealing with the same loci in making comparisons between the loci of the two maps, which is not possible in other species of *Drosophila*. The maps of the chromosomes I, II, and III have been improved so that better comparisons can be made with the corresponding three chromosomes of *melanogaster*. The most striking result of the comparison has been the discovery of a difference in sequence in three identical loci in chromosome III. Thus, in *melanogaster* the order is scarlet, pink (peach), Delta; while in *simulans* the order is scarlet, Deltoid, peach. Equally interesting is the difference in cross-over values. Thus scarlet and peach in *simulans* are approximately 75 units apart, while in *melanogaster* they are only 3 units apart.

In connection with the work on other species of *Drosophila*, an examination has been made of types in the British Museum and in the museums at Lund and at Amsterdam. The object of the examination was to straighten out the taxonomy of American and other forms.

The possession of a stock containing triploid (3n) individuals, recorded in the last report, furnishes an opportunity to study the possible relations between the presence of three "homologous" chromosomes and the phenomena of equational non-disjunction, also an opportunity to examine into what influence such a triune relation may have on crossing-over. Stocks are being prepared, suitable for such work, in which 5 loci are marked on each of the 3 X-chromosomes of each 3n female.

From time to time we have made attempts to get some idea of the number of genes in *Drosophila*. Several methods have suggested themselves, but we have realized that the data could at best furnish only limiting values. If the number of genes could be even roughly estimated, and if we could determine the length of the actual chromosomes, it would be possible to get some idea as to the limiting values for the size of the genes themselves. We have approached the question with many misgivings, realizing the inadequacy of the data and realizing also that no matter how cautiously the results are stated, they will be quoted and the reservations forgotten. However, by pointing out at each stage of the calculations the sources of error, we feel that we have done all that is necessary to guard ourselves against misrepresentation. Without going into the methods of procedure here (they will be briefly given in the Croonian Lecture for 1922), it may be stated that the calculations place the size of the gene somewhat beyond the range assigned to hemoglobin molecules. If further work confirms this view, then it follows that the changes in the genes, that we call mutations, are of the order of magnitude of molecular phenomena.

The work on chromosome III of *Drosophila* is now ready for publication. In addition to a description of all the mutant races known to us to the end of 1921, the data are given on which the location of the genes is based. A full account of the methods in which the raw data are handled in order to get as accurate positions as possible for the genes in the chromosome maps is given in detail. We hope this complete account of the procedure may show what corrections of the data are necessary in order that the placing of the genes may serve to meet the situations most often encountered.

CHEMISTRY.

Noyes, Arthur A., California Institute of Technology, Pasadena, California. *Researches upon (1) the properties of solutions in relation to the ionic theory; (2) a system of qualitative analysis including the rare elements; (3) the determination of the structure of crystalline substances by X-rays; (4) the chemistry of substances at very high temperatures; (5) the effect of radiations and electric discharges on the rate and equilibrium of chemical reactions.* (For previous reports, see Year Books Nos. 2–20.)

In November 1921, the Trustees of the Carnegie Corporation of New York appropriated funds to the Carnegie Institution of Washington to be applied for a period of five years in the support of fundamental researches in physics and chemistry at the California Institute of Technology. A portion of this appropriation for the year 1922 was allotted by the Institution to Dr. A. A. Noyes for his researches in chemistry relating especially to the nature of matter. Reports relative to the additional investigations undertaken with such assistance will be found principally under the fourth and fifth sections which follow.

1. Properties of Solutions in Relation to the Ionic Theory.

A research on the electrode-potential of bismuth has been carried out by Dr. David F. Smith. This consisted in measurements of the conductivity of solutions containing varying quantitities of bismuth oxide dissolved in perchloric acid at a series of concentrations, made with a view of determining the state in which bismuth exists in these solutions, and in measurements of the electromotive force of cells of the type

$$Bi(s), \begin{Bmatrix} Bi(ClO_4)_3 \\ HClO_4 \end{Bmatrix}, HClO_4, H_2(1 \text{ atm.})$$

The molal electrode-potential of bismuth, the constant determining its reducing power in the electromotive series of elements, was found to have the values -0.30 ± 0.01 volt against a solution 1 formal in total bismuth and 1 molal in hydrogen ion. It is therefore somewhat more reducing than copper, whose potential against 1 molal cupric ion is -0.345 volt.

The molal electrode-potential of bismuth has also been derived by Mr. E. H. Swift by an entirely independent method—that of determining the equilibrium conditions at 25° of the reaction between metallic bismuth and copper and their perchlorates in aqueous solution. This research leads to nearly the same value of the bismuth electrode-potential.

With the assistance of Mr. Laurence E. Weymouth, the free energy of formation of solid sodium hydroxide, NaOH(s), from its elements has been determined by an indirect method, which has some interest because of the principles involved. This constant was derived, namely, by combining the results of measurements of the electromotive forces of the two cells

$$\text{Na in Hg, NaOH(s) under } C_5H_{11}OH.nH_2O, H_2(g)$$

$$\text{Hg+HgO(s), NaOH(s) under } C_5H_{11}OH.nH_2O, H_2(g)$$

This value is of significance as being the free-energy of formation of an important alkali-element hydroxide—the first that has been determined; but it was studied especially in order to enable an estimate to be made of the extent to which it dissociates in flames—information needed in interpreting the results of an investigation referred to below.

2. System of Qualitative Analysis including the Rare Elements.

An attempt has been made during the past year, with the assistance of Professor W. C. Bray and Mr. E. H. Swift, to bring to a conclusion the research on a system of qualitative analysis including all the metallic elements which was carried out through a long period of years at the Massachusetts Institute of Technology. Good progress has been made; and there is reason to hope that during the coming year the work may be completed and published as a monograph. A new and complete, but fairly simple, procedure for preparing the solution for analysis, by which practically all materials, even the most difficultly decomposable, are brought into solution, has been fully worked out. The method of analysis of the group of elements (comprising arsenic, selenium, and germanium) which distil over upon boiling with hydrobromic acid, and of the group of elements (comprising antimony, tin, tungsten, molybdenum, vanadium, titanium, tantalum, and columbium) which may be left as solid oxides after treatment with concentrated nitric or perchloric acid, has been brought into final form. The rest of the scheme of analysis is so far advanced that the main work remaining is its preparation for publication.

3. Determination of Structure of Crystalline Substances by X-Rays.

The investigations on the determination of the arrangement of atoms in crystals have been continued by Dr. R. M. Bozorth and Mr. A. L. Raymond, with the close cooperation of Dr. R. G. Dickinson, who as National Research Fellow is pursuing researches in this field in the laboratory. The work during the past year has also been greatly promoted by the presence of Dr. R. W. G. Wyckoff, member of the staff of the Geophysical Laboratory, who, under leave of absence generously arranged for by the Director of that Laboratory, has been in residence at the Institute as one of its Research Associates.

While during previous years this field of research had seemed to be yielding returns only slowly and laborously, yet, now that the methods of study have been more fully developed and the types of crystals are known which lend themselves to satisfactory interpretation, a wealth of interesting results is being rapidly accumulated. Thus, the atomic arrangement and atomic distances have been fully or in large measure determined in the following complex salts: K_2SnCl_6, $(NH_4)_2SnCl_6$, $K_2Zn(CN)_4$, $K_2Cd(CN)_4$, $K_2Hg(CN)_4$, K_2PtCl_4, K_2PdCl_4, and $(NH_4)_2PdCl_4$, by Dr. Dickinson; $(NH_4)_2SiF_6$ by Dr. Bozorth; $NiCl_2.6NH_3$, $NiBr_2.6NH_3$, $NiI_2.6NH_3$, and $Ni(NO_3)_2.6NH_3$, by Dr. Wyckoff. Silver molybdate Ag_2MoO_4, hydrazine hydrochloride $N_2H_4(HCl)_2$, sodium acid acetate $NaC_2H_3O_2.HC_2H_3O_2$, and zinc bromate hexahydrate $Zn(BvO_3)_2.6H_2O$ have also been investigated by Dr. Wyckoff; phosphonium iodide PH_4I, by Dr. Dickinson, and cadmium iodide CdI_2, by Dr. Bozorth. Conclusive results have been obtained by Dr. Dickinson and Mr. Raymond with hexamethylene tetramine $(CH_2)_6N_4$, the first non-saline organic compound to be successfully studied by the X-ray method. Of special interest is the fact that this compound, unlike the inorganic ones thus far investigated, shows a distinct segregation of its characteristic molecules.

The experimental facilities for the execution of these researches have been supplemented by securing from the General Electric Company one of their newly developed, water-cooled X-ray tubes, with its auxilliary equipment, the greater power of which will make possible the study of certain substances that are obtainable only in the form of crystalline powders.

4. The Chemistry of Substances at High Temperatures.

This line of research and the one described under 5, which are the main ones to be undertaken with the aid of the increased resources now available, have already been initiated. The study of the chemical compounds that are formed in increasing proportion under the influence of very high temperatures or of powerful radiations is not only important from the standpoints of pure and applied chemistry, but of great interest to astrophysicists, because of the aid it may be expected to afford in interpreting solar and stellar phenomena. The cordial assistance which members of the staff of the Mount Wilson Observatory have afforded assures successful cooperation in the prosecution of these investigations.

The first work that has been undertaken in the high-temperature field has for its purpose the experimental confirmation of the theory of Saha in regard to the thermal ionization of elements by reactions such as $Na = Na^{+} + E^{-}$, where E^{-} represents the negative electron. This theory has received great attention from astronomers because of the explanation it affords of many spectral phenomena. A study of the literature showed that there exist investigations on the electrical conductivity of flames which can be utilized in testing the Saha theory; and in cooperation with Professor H. A. Wilson, of the Rice Institute, who carried out the most complete of these investigations, papers have been prepared and presented in outline before the National Academy of Sciences and published in detail in the Astrophysical Journal and Journal of the American Chemical Society, in which it is shown that the experiments on the conductivity of gas flames into which salt solutions have been sprayed afford, within the rather large limits of error of these experiments, a striking confirmation of Saha's conclusions.

In order to obtain conductivity measurements of salt vapors under more definite conditions of temperature and pressure than is possible in flames, an investigation has been undertaken at the Mount Wilson Observatory by Dr. A. S. King of that institution, in cooperation with Professor A. A. Noyes of this laboratory. The apparatus, consisting of an electric furnace in which is heated a graphite tube provided with a concentric electrode, through which nitrogen gas charged with a known proportion of salt vapor is passed, has been constructed and used for preliminary measurements.

Another distinct but related line of research, for which preparations are being made, is the determination of vapor-densities of substances at very high temperatures. For this purpose arrangements have been made with the Research Laboratory of the General Electric Company for the construction of a molybdenum bulb of the Viktor-Meyer form, which can be heated to about 2400° C. This has been made possible by the friendly assistance of the director, Dr. W. R. Whitney, and of the Assistant Director, Dr. W. D. Coolidge, of that Laboratory. We are also greatly indebted to Dr. R. C. Tolman, former director of the Fixed Nitrogen Research Laboratory, and to Dr. Karrer of that Laboratory, for the aid they afforded in working out the best method of heating the molybdenum bulb in an induction furnace.

5. Effect of Radiations and Electric Discharges on the Rate and Equilibrium of Chemical Reactions.

During the past year an investigation has been carried out by Dr. D. F. Smith, in this laboratory, on the rate of decomposition at 280° to 350° of gaseous sulphuryl chloride in accordance with the equation $SO_2Cl_2 = SO_2 + Cl_2$. This reaction has been proved to take place without the aid of catalysts in the mass of the gas, and to be clearly of the unimolecular type. Thus it adds another reaction of this character to the very few previously discovered; and, when the experiments are completed, it will make possible further testing of the various quantum radiation hypotheses that have been proposed to account for the rate of chemical reactions.

Work is also in progress on the effect of ultra-violet radiations on the rate of decomposition of hydrogen iodide into hydrogen and iodine.

With the coming of Dr. R. C. Tolman to the laboratory this autumn, researches on the effect of electric discharges on the rate of chemical reactions, and especially on the production and behavior of active forms of the various elements, are to be undertaken by assistants working under his direction.

Richards, Theodore W., Harvard University, Cambridge, Massachusetts. *Continuation of exact investigation of atomic weights and other physico-chemical properties of elements and of simple compounds.* (For previous reports see Year Books Nos. 2–20.)

The following investigations have been in progress during the academic year, some of them continuations of work begun a year or more ago.

1. The Separation of Lead Isotopes.

This investigation has been continued by Mr. Harold S. King, and is drawing to a close. The various samples of different fractions of lead obtained by the Grignard process and by the fractional volatilization of lead at apparently low temperature in an X-ray vacuum are now being compared as to their densities by means of a very precise method of density determination. This procedure seemed likely to yield a more definite result than the determination of atomic weights, since the percentage accuracy of the method is greater, and since the differences to be expected are very small.

2. The Atomic Weight of Rubidium.

Miss Edith H. Lanman, continuing the investigation upon the atomic weight of rubidium, has analyzed many of her samples of extremely pure rubidium chloride. The result for the atomic weight of rubidium is 85.43, a value not very far from the value of Archibald.

3. The Atomic Weight of Gallium.

Mr. William M. Craig has completed a number of preliminary analyses and five final determinations of the atomic weight of gallium, by the analysis of gallium chloride. The result for this atomic weight is 69.716, a value which gives probable evidence that gallium is composed of at least two isotopes. A complete account of the investigation will be published in the near future.

4. The Atomic Weight of Copper.

Mr. Arthur W. Phillips has undertaken the study of the atomic weight of copper, using samples of copper from widely different localities and widely different geologic ages. This investigation was begun not only to verify the accepted value determined thirty years ago, but also to discover if widely different samples might possibly consist of different mixtures of the isotopes which undoubtedly constitute this elementary substance.

5. THE HEAT OF REACTION OF SLOW CHEMICAL PROCESSES.

Mr. Oscar C. Bridgeman, continuing the study of this problem, has carried out with his exceedingly complicated apparatus a number of careful determinations of the hydrolysis of methyl acetate, ethyl acetate, and propyl acetate. The results with each of these substances were highly consistent and the apparatus functioned without fault. These results are almost ready for publication.

6. THE COMPRESSIBILITIES OF SIMPLE SALTS.

Mr. Edouard P. R. Saerens, Belgian Research Fellow, continued the study of the compressibility of various simple salts. To results for halides of the alkali metals he has added results for the compressibilities of calcium, strontium, and barium chlorides which show systematic relation to one another and which afford interesting basis for theoretical conclusions.

(For example, see Sir J. J. Thomson's paper in Phil. Mag. (6), 43, 721 (1922).)

7. THE ELECTROCHEMICAL BEHAVIOR OF BARIUM AMALGAMS.

Mr. Paul A. Anderson has undertaken the study of the electrochemical behavior of barium amalgams. This problem is somewhat similar to the problems of sodium and thallium amalgams discussed in previous issues of this report, but the new problem is more difficult and presented several troublesome features. The chief difficulties seem now to have been mastered, however, and preliminary results are already at hand.

8. THE MOLECULAR COMPLEXITY OF WATER.

Mr. Harris M. Chadwell has undertaken the investigation of the molecular complexity of liquid water, and during the winter has carried out many determinations of the densities, compressibilities, and coefficients of expansion of aqueous solutions of various non-electrolytes with the object of evaluating the volume changes manifested by water when such substances are dissolved in it, and with the hope of interpreting these changes in relation to the degree of association of water molecules. This study has involved, as one of its corollaries, the study of the various methods of evaluating internal pressures in liquids.

9. BEHAVIOR OF OXYGEN AND HYDROGEN ELECTRODES IN AQUEOUS SOLUTIONS.

Mr. William T. Richards has studied critically the behavior of oxygen and hydrogen electrodes in aqueous solutions of widely different composition. He has also investigated the distance-effect of chemical affinity and has attained results proving that on the nearest possible approach solids having strong chemical affinity for one another nevertheless exert no mutual attraction measurable on an analytical balance. Evidently, then, chemical affinity acts at only exceedingly short range.

10. ANALYSIS BY CENTRIFUGAL ACTION.

Dr. Olof Arrhenius, in an independent investigation, devised a convenient rapid method for quantitative analysis by centrifugal treatment for use in a comprehensive study concerning plant physiology. Because the centrifuge and some other apparatus which he used belonged to the Carnegie Institution, mention of this work is appropriate here.

Since the last report nine papers have been published concerning work more or less supported by grants from the Institution. Among these papers are several which nearly complete the publication of recent thermochemical work conducted with these grants.

Sherman, H. C., Columbia University, New York, N. Y. *Chemical Investigation of Amylases and Related Enzymes.* (For previous reports see Year Books Nos. 11–20.)

The experimental study of the influence of amino acids upon the enzymic hydrolysis of starch, which was discussed in the report of last year, has been extended with results which throw additional light upon the chemical nature of the enzyme, and an investigation of the isoelectric points of the amylases has been begun.

A notable feature of the work as previously reported was the fact that histidine and tryptophane did not increase the amyloclastic activity of the enzyme, as did all of the monoamino acids which we have tested. It was barely conceivable that this might have been due to traces of mercury accompanying these two amino acids as an impurity through having been used as a reagent in their preparation. This remote possibility has now been disposed of by experiments in which it has been shown that mercury, like copper, does exert a deleterious or inhibitory effect upon the unprotected enzyme; but that the presence of amino acid protects the enzyme from inactivation by mercury, as it does from inactivation by copper. These experiments have been completed and the results prepared for publication.

On extending the work with the basic amino acids, it has been found that lysine resembles histidine and tryptophane in not increasing the amyloclastic activity of pancreatic amylase, while both lysine and tryptophane do increase its saccharogenic activity. (The effect of histidine upon saccharogenic activity can not be tested in the same way, because its presence interferes with the determination of the sugar formed.) That lysine is without influence upon the amyloclastic action, but does favorably influence the saccharogenic activity of the enzyme, and that tryptophane shows similarly contrasting results when tested for its influence upon these two phases of enzyme activity, are findings which lead to considerations of much theoretical interest. Previous studies of pancreatic amylase have tended to indicate a closer parallelism between the two phases of activity of this enzyme. The quantitative values of the amyloclastic and saccharogenic powers of different preparations from the pancreas have shown an approximately constant relation to each other. The same concentrations of hydrogen ion and of sodium chloride and disodium phosphate appear to be required for optimum amyloclastic as for optimum saccharogenic activity. When two representative monoamino acids, glycine and phenylalanine, were tested for their influence, first upon the saccharogenic and then upon the amyloclastic activity of pancreatic amylase, both substances showed favorable effects in each case. The results obtained with lysine and tryptophane, however, emphasize the fact that amyloclastic and saccharogenic activity are to some extent different properties of the amylase. If there were no other evidence, these two activities would usually be attributed to the presence of two different enzymes in the amylase preparations used; but the ratio of amyloclastic to saccharogenic activities of the purified amylase preparations remains practically the same as in the original pancreatin from which they are made, and it appears improbable that two distinct enzymes would pass through the various operations of the purification process without change in their quantitative relations to each other. Of particular interest is the fact that it is the first (amyloclastic) phase of the enzyme's activity which is not influenced by lysine and tryptophane, while the later (saccharogenic) phase is favorably affected. This, interpreted according to the theory outlined in our report of last year, is an indication that the lysine and tryptophane radicles of the enzyme molecule are so bound therein as not to be liberated by hydrolysis until after the enzyme has passed the amyloclastic stage of its action, which is a property having to do with the earliest phase of the starch hydrolysis; whereas the saccharogenic activity is chiefly exerted later, and in this later phase of its activity the enzyme (which may have already lost its amyloclastic power) is to a measureable extent protected by the presence of added lysine or tryptophane from such further hydrolytic change as would result in the loss of its saccharogenic activity. The work with lysine has been completed and the results prepared for publication.

As mentioned in the report of last year, an earlier explanation, chiefly due to Rockwood, of the favorable effect of amino acids upon the activity of amylases, is that they exert a direct activating influence by virtue of the chemical groupings which they contain. If this were the case, similar groupings in other organic compounds should also show favorable effects when tested upon the enzyme under the same conditions. In order to test this question, a careful study of several types of pure organic compounds has been made. Aniline, methyl- and ethyl-amines, benzoic acid, benzamide, and anthranilic acid collectively contain the amino group and the carboxyl group both singly and in different combinations, but none of these substances showed a favorable influence upon salivary or pancreatic amylase, when tested under standard conditions in the presence of optimum concentrations of hydrogen ion and of sodium chloride and disodium phosphate. Our knowledge of the structure of protein molecules is not sufficiently complete to enable us to select for test any simple α-amino acid with assurance that it is not a possible product of protein hydrolysis; but if the α-amino acid grouping is of itself the cause of the favorable influence of glycine, for example, it would appear that the same property should be shown by hippuric acid (benzoyl-glycine), especially since the benzoyl group has in other experiments been found to be without effect. Hippuric acid, however, when tested under standard conditions, failed to show any favorable influence. The net result of a large number of experiments, which we have made with carefully selected substances, is that they fail to furnish any support for the view that certain organic groupings as such activate amylolytic action.

On the other hand, the theory that the enzyme molecule, or an essential part of it, is of a protein nature, subject to hydrolysis into amino acids in the aqueous dispersions in which it acts, and therefore capable of being better preserved by the addition of a suitable amino acid to its dispersion medium, is supported both by the experiments with lysine and tryptophane above mentioned and by further experiments in which the effect of certain amino acids upon the deterioration of pancreatic amylase in solution has been tested directly. The extent of the deterioration of this enzyme when allowed to stand in solution for different lengths of time and at different temperatures with and without the addition of amino acid has been determined. It was found, for example, that a solution of pancreatic amylase (containing optimum concentrations of chloride and phosphate) which had stood for one hour at 40° C. showed about one-third greater activity when alanine had been added to the solution in advance. If protection against hydrolytic destruction is an explanation of the increased activity of amylase in the presence of amino acid, it is logical to expect that any condition favoring the hydrolysis of the enzyme molecule, such as a higher temperature or subjection to a given temperature for a longer time, would result in a greater apparent effect from the added amino acid. This has been found to be the case. A series of experiments, in which pancreatic amylase has been allowed to act for periods of 30 and of 60 minutes at temperatures ranging from 30° to 75° C. has shown the favorable effect of the amino acid to be greater for the longer period and to increase with rise of temperature up to the point at which coagulation of the enzyme occurs. The results of these latter experiments are now being prepared for publication.

In view of the strong evidence that our typical amylases are in their chemical composition essentially protein substances, and the growing importance of a knowledge of the isoelectric points in working with such substances, an attempt has been made to work out a method for the determination of isoelectric points of amylases by means of a series of electrophoresis and precipitation experiments. For the preliminary experiments thus far performed a commercial malt extract has been used because malt amylase is more stable in water than is pancreatic amylase. These experiments have shown the presence in the extract of inert proteins of widely different isoelectric points, and it is hoped that this work may furnish a basis for improvements in the methods of purifying the enzyme. Having now developed a technique which appears to be suitable for electrophoresis experiments upon materials of the sort with which this investigation deals, we hope to extend this phase of the work actively during the coming year.

The efficient collaboration of those who shared in these investigations, whether as research assistants or volunteers, is gratefully acknowledged.

ECOLOGY.

Clements, F. E., Tucson, Arizona. *Associate in Ecology.* (For previous reports see Year Books Nos. 16–20.)

As usual, the experimental work of the growing-season has been centered at the Alpine Laboratory from June 1 to September 15, while studies of the volume and composition of soil-air and plant-air have been continued during the autumn and winter. Further investigations in the water-cycle series have been made at the Desert Laboratory during winter and spring, and the ecological relations of latex have been under examination at the University of California. Statistical and garden studies of the Madieæ, Haplopappus, and other genera have been continued at the same institution, and a Sierran transect for experimental evolution, a complement of the Petran one at Pike's Peak, has been installed from Mather through Tioga Pass into the sagebrush desert at Benton. The absorptive processes of roots have been further investigated at the University of Nebraska, and a field station has been installed at Greeley, Colorado, for experiments in root behavior under irrigation. The series of stations for experimental vegetation and crop ecology has been maintained as usual.

Vegetation studies were carried on actively throughout southern Arizona during the winter and formed the chief objective of several field expeditions. The first traversed the Colorado Desert and the coastal region of California, and dealt especially with relict dominants, the grasses in particular, and with other evidences of climatic changes. The second crossed the Great Valley of California and the Sierras and passed through central Nevada and Utah, devoting the chief attention to the structure and relations of the climaxes, the seral position of the sagebrush dominants and the significance of relicts as climatic indicators. The third expedition traveled through eastern Utah, southern Wyoming, and western Nebraska and made a study of the general relations of climate and sedimentation in classic bad-land regions of the Eocene, Oligocene, and Miocene. The route of the fourth expedition was through northern Kansas and southern Nebraska to eastern Kansas, Oklahoma, and southeastern Texas, and then westward along the border to Arizona. Its primary objectives were the ecotone between forest and grassland on the east, the contact between postclimax scrub and the desert plains on the south, and the movement of grassland dominants in relation to grazing and climatic shifts.

FACTOR STATIONS.

Four series of factor stations have been maintained during the year. The most extensive is the one established for the past 5 years in the associations of the grassland formation from the subclimax prairie of eastern Nebraska to the mixed prairie of eastern Colorado and devoted to the measurement of the factors efficient in crop production and ecesis. The second is installed at the Alpine Laboratory in the montane zone for the study of the factors responsible for the differentiation of vegetation on north and south slopes. The third has been established at Greeley, Colorado, for the interpretation of the conditions under which roots develop and crops are produced in dry land and under half and complete irrigation. The fourth series is located in the desert plains grassland of the Santa Rita Range Reserve south of Tucson to determine the effective factors in the growth of the communities of winter annuals, and in the differentiation of the structure of the climax itself.

The Phytometer Method, by F. E. Clements, G. W. Goldsmith, and J. E. Weaver.

Additional tests of the phytometer method have been made in order to perfect sealing methods and to determine the limits of individual variability in transpiration. Although paraffin-cloth has furnished a satisfactory sealing method, ceresin applied in the same manner has proved to be somewhat better adapted to the high surface temperatures encountered in the region. Plants and blanks sealed with ceresin on cloth gave very satisfactory results when protected against the midday heat by a cloth insulator, the latter preventing the cracking of the seal with the contraction and expansion incident to temperature changes. Poured wax-seals were unsatisfactory when used for containers of more than a decimeter in diameter, owing to the effect of temperature changes. Plastocene modeling clay covered with tin-foil gave results as satisfactory as those obtained with ceresin, but was much harder to apply to the phytometers and was more expensive.

Individual sunflowers were found to vary as much as 20 per cent in the transpiration per square decimeter under identical conditions of soil and exposure. However, the effect of this variation was eliminated by selecting the plants for each battery in such a way as to give the three batteries the same average transpiration. The individual variation in transpiration is being studied in pedigreed wheat and oats with the object of selecting a strain showing the minimum of variability, and it is hoped to find a strain of native sunflowers that will yield the same result. The application of the phytometer method during the year has been made chiefly in the slope-exposure studies described below.

Slope-Exposure Studies, by F. E. Clements and Dolly Lutjeharms.

In continuing the investigation of the efficient factors on north and south slopes, the three original stations have been maintained and three new ones established. The latter are located on the same slopes, but in such fashion as to avoid the wind-drift over the summit, with the possibility of changing the normal conditions. Air and soil temperatures, water-content, humidity, evaporation, wind, and rainfall have again been measured throughout the season for the six stations. The soil temperatures have been determined in the new series at depths of 4 and 12 inches, and the light intensities measured by means of chemical photometers, as well as the selagraph. Each station was also provided with a battery of phytometers installed and handled as during the preceding year, but compensated for individual variability in transpiration.

The instrumental results show that the air temperature and humidity of the two slopes were similar during the first half of the summer, but later the south slope exhibited a wider fluctuation than the north, as well as an average higher temperature and lower humidity. The station at Ruxton Brook is much more equable, with the air temperature regularly a few degrees lower and the humidity higher than on the north slope. The soil temperature at both 4 and 12 inches on the south exposure averages from 12 to 20 degrees higher than on the north, with the brook station again a few degrees lower than the latter.

The transpiration rate on the south exposure is very high, with an average loss of three times as much water as on the opposing slope. The sunflower phytometers gave the most striking results, the plants on the south slope being shorter, the stems densely pubescent, with woody bases, and the leaves thicker and forming a dense terminal rosette. The plants of the north slope were taller, stems less pubescent and but slightly woody, and the terminal rosette larger and more open, while those at the Ruxton were intermediate. The growth of the root-systems corresponded closely to the transpiration rate, being greatest on the south slope, least at the brook station, and intermediate on the north slope.

The Water Cycle in Plants, by F. E. Clements and J. V. G. Loftfield.

In tracing the detailed movement of water in the plant, the present emphasis is placed upon the concentration of the cell-sap, especially in the epidermis, and the conductivity of vascular systems. A modified type of freezing-cell has been devised for the former, and certain difficulties in supercooling and the transfer of water before and after freezing have been solved. In the epidermis of *Populus tremuloides* the guard-cells varied from 2.56 atmospheres when closing rapidly to 23.2 atmospheres at the time of opening, while the epidermal cells ranged from 6.41 to 7.20 atmospheres. A distinct gradient was evident between the guard-cells and the adjacent circles of cells, strips collected at 4 p. m., for example, showing the former freezing first, and, after an appreciable drop in temperature, the successive rows of epidermal cells freezing in turn. The melting-points of the cell-sap alone were recorded in concentration readings because of supercooling, and in most of the plants tried even this point was found more or less unreliable. For this reason the plasmolytic method is being refined as a check or a substitute in freezing determinations.

The conductivity of the vascular system of the shoots and roots of both woody and herbaceous plants is being investigated by means of a modification of Farmer's apparatus. At the outset an endeavor was made to determine the limits of variation for stems of the same length, position, and age, as a guide in the further analysis of their behavior. In all the plants studied, the successive sections of an unbranched stem show an increase in both specific and absolute conduction from the base to the top. In many cases the length of the stem has practically no influence, a long stem showing the same amount of conduction as its parts, except when these vary greatly. Under the latter condition its conductivity is determined by the section with the minimum rate, a relation found to hold in *Acer glabrum*, *Betula fontinalis*, and *Helianthus annuus*. Conduction through nodes of the sunflower is invariably greater than through the adjacent internodes. On the other hand, conduction through the transition region of stem and root has been found to be considerably less than through the neighboring root or stem in the case of *Prunus demissa* and other species.

Transpiration and Stomatal Movement in Cereus giganteus and their Correlation with Variations in Stem Diameter, by J. V. G. Loftfield.

The study of variations in the stem diameter of the trunk of *Cereus* gave a behavior directly opposite to that of the trees previously investigated. While the trunks of conifers expanded at night and contracted by day, the trunk of the sahuaro enlarged during the day and diminished during the night. This was thought to be related to the stomatal movement, and several series were made to determine the latter during the 24 hours, together with measurements of transpiration. A close correspondence was disclosed between water-loss and stomatal movement, and a causal connection between the former and changes in trunk diameter. The stomata of *Cereus* were found to open gradually through the night after 6 p. m. and to close before noon of the next day, while the rate of transpiration increased and decreased with the degree of stomatal opening. Hence, it was greatest during the night and had disappeared by the middle of the day. The trunk regularly expanded when the stomata were closed and transpiration prevented, and contracted when the latter again became appreciable. Expansion of the trunk occurred during the day at a time when other plants were dying or shedding their leaves for lack of water, indicating that the echard is much lower for this species.

Studies in Aeration, by F. E. Clements and G. W. Goldsmith.

Further work on the dissolved gases in bog-water indicates that, while the oxygen-content of the lower levels may be reduced beyond the sensibility of the Winkler method, the carbon dioxid and the acidity vary in proportion to the photosynthetic activity of the algal flora. The bogs at high altitudes in the Pike's Peak region are anaerobic during the winter, when the ice prevents active gas interchange with the air, and at such times are often charged with H_2S. During the summer the surface water is in approximate gaseous equilibrium with the air, but anaerobic conditions usually persist at a depth of a meter or more. In the open pools, where light intensities permit the growth of algæ, anaerobic conditions prevail only well below the algal zone.

The field study of soil-air and of the acidity and gases of the soil-solution has been extended to include mesophytic and xerophytic habitats. A complete portable outfit for the field has been developed for measuring the volume of soil-air, as well as its composition. The results so far obtained indicate that the accepted estimates of the amount of air in various soils are too high. Measurements are also being made of the amount and composition of the air in the roots and stems of plants, especially amphibious ones, and the earlier experiments on aerotropism and the behavior of roots under anaerobic conditions have been resumed and extended.

Photometers and Photometric Methods, by F. E. Clements and J. V. G. Loftfield.

The simple photometer and the selagraph or recording photometer developed more than 20 years ago have been improved and modified to form a series of instruments which now includes the stop-watch photometer, water photometer, selagraph, water selagraph, and a portable electric spectrophotometer. The simple photometer has been largely replaced by the stop-watch one, which is much more accurate and convenient to use, and the water selagraph is designed to replace the water photometer, which must be turned for each exposure and hence is hard to operate at considerable depths.

While the solio paper used in the photometers and the azo paper employed in the selagraphs have given dependable results in a wide variety of investigations, their value is now being tested by means of bromide papers sensitized with sodium nitrate and by this with erythrosin, according to formulæ kindly furnished by Dr. C. E. K. Mees, of the Eastman Laboratories. In addition, the Ridgway chemical photometer is being tried out in the expectation that it will afford a check on the photographic method, and a new colorimetric photometer that makes use of chlorophyll is being developed. A paper is now in preparation dealing with the series of photographic photometers and the spectro-photometer and their uses.

Methods and Principles in Experimental Pollination, by F. E. Clements and Frances Long.

In a final extension and checking of the results of the past 5 years, further experiments have been made as to the response of insects to color, odor, mutilation, and artificial flowers and to determine the relative attraction of different species when competing with each other. Life-histories have again been traced in detail, and a method of observation and record has been devised for the florets of composites and grasses. The observations on the normal behavior of the principal pollinators have been extended, and the number of pollen-loads weighed and analyzed has been greatly augmented. A particular endeavor has been made to follow the behavior of *Bombus*, especially during the interval between the maximum flowering of two preferred species. In connection with the relative efficiency of flowers as to pollen deposit, many permanent mounts of pollen-grains and stigmatic surfaces have been made.

The summer's work has confirmed the general conclusion, already reached, that habit is the most important factor in the behavior of pollinators, though the influence of habit varies with the group, species, age, season, time of day, and other considerations. Contrary to Plateau's views, color appears to be more controlling than odor, except in flight from a distance. In the effort to give greater currency to the experimental study of pollination, an exhaustive summary has been made of all previous researches that have made use of experiments, and detailed attention has been given to the complete work of Plateau and his critics. While it is planned to extend the investigation into the alpine climax and to the Pacific Coast next summer, the results of the present series of experiments are now being brought together for publication.

Factors Involved in the Opening and Closing of Flowers, by G. W. Goldsmith and I. M. Johnston.

In connection with pollination experiments, it has proved desirable to scrutinize the results obtained in earlier investigations and to initiate a new series of studies to deal more accurately with the factors and conditions concerned in the field. In the case of *Mentzelia multiflora*, the flowers open regularly between 4 and 5 p. m., the younger flowers closing about 8 o'clock and the older ones remaining open until the following morning. When plants were placed in bell-jars heated by means of a steam-coil and the temperature kept at 25° C., the time and speed of closing were not perceptibly changed, even though the temperatures were maintained for several hours before the time of opening. However, it was possible to prevent closing by such means, while the removal of the bell-jars usually resulted in closure within a half hour. Thus, a fall in temperature seems to be responsible for normal closing, but opening appears to be independent of the usual changes in temperature and is apparently related to turgor. If stems are cut and the ends placed in water, there is usually no movement for the next 24 hours, regardless of changes in temperature or light. Closed flowers fail to open, and open ones do not close until the following day, unless the water is under approximately the pressure of one atmosphere, when the normal movements take place. With *Oenothera cæspitosa* a temperature of 25° C. kept flowers closed for 1 to 2 hours after normal opening had occurred outside, while the removal of the bell-jar caused them to begin opening at once and to reach full expansion in about an hour. Lowering the temperature 10° to 12° from 2 until 6 o'clock maintained closure after normal opening had begun. It is planned to continue the investigation until several examples of the various types of hemeranthous, nyctanthous, and ephemeral flowers and heads have been passed in review.

Correlation in Bud Development, by F. E. Clements.

In the course of a comprehensive study of the movement of food within the plant, an earlier experimental series in bud development has been resumed and continued during the past 3 years. This has dealt chiefly with *Melia* and *Populus*, but *Fraxinus*, *Salix*, *Prunus*, and *Morus* have also been taken into account, and it is expected to extend the investigation to include the major types of buds, including herbaceous ones. In addition to extensive observations of the normal behavior of shoots and sprouts in various positions, the following experimental methods have been employed: (1) change of position of shoot, both before and after the opening of buds; (2) transfer of shoots to water, nutrient, and food solutions; (3) removal of buds from the shoot in varying manner and position; (4) supplying sugars, water, etc., to individual buds or shoots; (5) wounding. While there was some variation in behavior, both observation and experiment showed that change of position to the horizontal or inverted was practically without effect upon the order of bud development in both leaf and flower buds. Furthermore, it was possible to develop any bud of a shoot by removing all the buds above or below it as the type of twig demanded, though this was less successful with flower buds, owing to their rapid expansion. For the addition of glucose a 2-inch section of thick-walled glass tubing was drawn out to a short point, which could be easily forced into the shoot, and this was filled with a 1 per cent solution of glucose and stoppered with a cotton plug. Checks were secured by employing similar tubes filled with water, as well as empty ones, to determine the effect of wounding alone. Each glucose tube was inserted a short distance above or below the bud to be forced, and the buds selected were largely those destined to remain dormant at the base of the twig in the ordinary course of development. In all cases the buds fed with glucose opened and the leaves expanded from 1 to 2 weeks earlier than those in the upper portion of the shoot, the rate of growth depending clearly upon the amount of sugar supplied. The evidence from all three sources, namely, change of position, removal of buds, and feeding with glucose, shows that development depended on the course taken by the food-laden sap in response to the competition for it. For the species employed the proof was conclusively against the hypothesis of an inhibiting substance that suppresses lower buds in consequence of the effect of gravity upon it.

Experimental Taxonomy, by F. E. Clements, H. M. Hall, and I. M. Johnston.

Transplant activities were greatly extended in California during the year. For this purpose a transect was selected which extends from the coast of San Mateo County across the interior valley and the Sierra Nevada to the sagebrush desert of Mono County. On this section practically all conditions and communities are to be found—from alpine to coastal on the one hand and to desert on the other. About 1,000 transplants, representing approximately 150 species and minor forms, have been made along this line and between California and Colorado. Special attention has been given to the preparation of the plants for transport, to the season of transfer, to the accuracy and thoroughness of vouchers and records, and to the protection of the transplants. Through the generous cooperation of certain landowners and the Government, it has been possible to inclose most of the California stations with permanent fences. When this was not feasible, as in the case of scattered plants, the experiments were located where least subject to injury from grazing animals or vandals.

The results of the year in the transplant gardens at Pike's Peak, especially with respect to reciprocal and variation transplants, have been carefully studied and new methods developed. In addition, a new alpine garden has been established for community transplants, in which actual meter quadrats of representative communities have been transferred from the alpine to the montane zone. An adaptation sequence has been organized in a series of 3 light values of approximately .07, .03, and .01, for the purpose of obtaining the complete response of stable and plastic heliophytes to shade and determining the limits of both adjustment and adaptation. In the hope of securing further evidence as to the effect of major climatic cycles, the most important dominants and subdominants of the mixed prairie at 6,000 feet have been transplanted to different altitudes to determine the limits of successful ecesis.

The Phylogenetic Method in Taxonomy, by F. E. Clements and H. M. Hall.

In order to emphasize the basic importance of phylogeny for taxonomic studies, monographs have been prepared of the North American species of 3 important genera, namely, *Artemisia*, *Chrysothamnus*, and *Atriplex*. The manuscript for these, together with a statement of principles and methods, has been completed, after several years of intensive field, garden, and herbarium studies, and submitted for publication. In addition to supplying much needed revisions of these economic groups, this contribution is designed to illustrate new or little-used methods of taxonomic research, especially the combination of field experiment and statistical studies and the introduction of exact quantitative criteria wherever possible. The attempt to express results in the most intelligible and useful form has emphasized the necessity of a species concept quite at variance with that of many present-day taxonomists. The category of subspecies is used for the major divisions of the species, while the still smaller units—ecads, mutants, races, biotypes, jordanons, etc.—are described only as numbered minor variations, since it is recognized that the naming of these is of value only to the extreme specialist. The number of such variations is so overwhelming that an attempt to name them all leads only to confusion, and the recognition of only a portion of them is illogical and futile. Moreover, their proper classification must await a close ecologic and genetic analysis, an undertaking not warranted at the present time. The phylogeny of the species and subspecies as now understood is graphically illustrated by a series of diagrams on which the principal differentiating characters are also indicated. These charts are so designed as to show the grouping of the smaller units into progressively larger ones, and they thus exhibit the degree of relationship between any two forms.

The Taxonomy of Haplopappus, by H. M. Hall.

The work on this complex group of the Compositæ has consisted largely of field studies on variation and the assembling of materials for garden experiment and statistical investigation. A few species have been transferred to new habitats in order to test the nature of their characters. Thus, *H. apargioides* of the non-alkaline meadows has been transplanted to alkaline soils of the desert borders, while *H. racemosus* of the latter habitat has been carried to the alpine meadows, about 20 plants of each species being used in the experiment. Intensive herbarium studies of the relationships of the subgenera, species, and smaller variations are now under way, with the object of presenting a detailed classification in the near future.

Rubber Plants, by H. M. Hall and Frances Long.

The work of the year on rubber plants has been restricted to the more intensive study of the most promising genera, *Chrysothamnus* and *Asclepias.* Samples aggregating several hundred pounds have been assembled and submitted to experts for tests as to the amount and quality of the rubber and fiber present. A considerable number of plants of *Chrysothamnus,* representing 5 different forms, have been brought into special gardens in California and Nevada for the study of variation, and some have been transplanted into fields to permit cultivation and selection.

Studies of *Asclepias subulata* at Sentinel, Arizona, show that its pollination is chiefly effected by *Anosia berenice.* The community of this species, which is the most extensive known at present, has been mapped to permit tracing its changes in detail from year to year, and some of the plants have been pruned annually to determine the effect upon the rubber-content of the different shoots and to throw light upon the possibility of harvesting the crop by mowing.

Latex and Laticiferous Tissue, by Frances Long.

Material of 75 species of latex plants has been collected and preserved for the study of variations in the development and occurrence of laticiferous tissue. A method of differentiating the rubber-content of latex vessels has been developed, in which the material is stained *in toto* and then sectioned. Microchemical tests have been used to determine the latex in various parts of the plant at different periods of growth, and special attention is given to the origin of laticiferous tissue, its function, and relation to other tissues.

In the hope of determining the factors that affect the latex-content, three of the most important species of *Asclepias,* namely, *subulata, sullivanti,* and *galioides,* have been grown in 5 different soils of known texture and water-content, from sand to clay loam. Seedlings of the same age were planted in pots of uniform size and placed under the same conditions. Soils were also made up with varying amounts of alkali, and the seedlings planted in these in sealed containers to permit determinations of the rate of transpiration and growth and the relation of these to latex production and rubber-content.

Absorption of Nutrients at Various Depths in Relation to Crop Yield, by J. W. Crist and J. E. Weaver.

The original problem has been extended to include not only the amounts of nitrates and phosphorus removed by crops at depths beyond the usual cultivation, but also the effect upon yield. Barley was grown under field conditions in containers large enough to permit normal root growth. The containers were filled in such a manner that the soil had the same relative position it occupied in the field. Before filling the containers, the soil from each level was thoroughly mixed, brought to the desired water-content, and certain levels impregnated with the proper amount of $NaNO_3$ or $Ca(HPO_4)_2$. The soil was separated into layers a foot or less in thickness by means of the usual wax seal, which is easily penetrated by roots but prevents the movement of water and solutes. Barley was grown in a row of 30 plants across each container, the latter being placed in trenches in the field and barley sown about them to simulate normal field conditions. Twenty-five containers were used, 9 for nitrate, 9 for phosphorus, 3 for control crops, and 1 without a crop for checking nitrification and denitrification.

The amounts of NO_3 absorbed where the soil was fertilized only in the first foot, at 1 to 1.5, 1.5 to 2, or 2 to 2.5 feet, were respectively 462, 291, 269, 312, and 134 parts per million. Where the fertilizer was placed both in the first foot and at 1 to 1.5, 1.5 to 2, or 2 to 2.5 feet, the amounts removed were 351 and 175 parts per million in the first case, 401 and 485 in the second, and 431 and 152 in the last. Thus, the total amount removed when an additional layer was fertilized was at least 14 per cent greater than the highest amount when any single layer was fertilized. In the series with single fertilizing the average height per stalk increased progressively from 55 cm. when the nitrate was in the first foot to 81 cm. when in the 2 to 2.5 foot layer. With double fertilizing it was slightly less than with single and much less than when the latter was in a deeper layer. The average height of the controls (65 cm.) was greater than in any of the double-fertilized series and also than in any of the single-fertilized, except at the depth of 2 to 2.5 feet. The plants of the phosphorus series averaged taller than those double-fertilized with $NaNO_3$, and also than those single-fertilized, except at depths greater than 1.5 feet.

The number of stalks per container decreased progressively from 60 to 36, depending upon the depth at which the nitrate was placed. In the double-fertilized series they varied in number from 65 to 71, considerably greater than the average number, 47, in the controls, thus indicating that double fertilizing promotes tillering, in addition to retarding the height growth of barley. This also gave an average weight of straw 42 per cent greater than for the controls and likewise increased the yield of straw over that obtained for a single application. The weight of grain was least for the single-fertilized series and was slightly less in the double one than in the controls. The nitrogen-content of the grain of the double series was practically the same for all combinations of depths of fertilizing. It was 35 per cent greater than that of the controls and 12.5 per cent more than where the fertilizer was placed in the surface foot alone.

Relation of Holard to Root Development and Yield, by F. C. Jean and J. E. Weaver.

Crops of Marquis spring-wheat, corn, alfalfa, sugar-beets, and potatoes have been grown in plots of one-thirtieth of an acre at Greeley, Colorado, on dry land and under semi-irrigated and fully irrigated conditions. The methods of preparing the seed-bed, tilling, etc., were essentially those of the usual farm practice, the main objective being to determine the effect of the different quantities of water on root development and yield. In addition to continuous records of temperature, humidity, and evaporation, the holard and the physical and chemical composition of the soil have been determined in the various fields. The root development of each of the crops was studied in several stages of growth under different environments. Marked differences in the root habits were found as well as in the crop yield, but the complete results will not be assembled until after another season's work.

Transplant Areas and Quadrats, by F. E. Clements and J. E. Weaver.

Studies in experimental vegetation were again carried on during 1922 by means of surface seeding and sowing in trenches and denuded quadrats and by transplanting seedlings as well as blocks of sod. The stations maintained were, as before, from the subclimax prairie at Nebraska City, Nebraska, to true prairie at Lincoln, Nebraska, mixed prairie at Phillipsburg, Kansas, and short-grass plains at Burlington, Colorado. At Lincoln the local stations ranged from xerophytic gravel-knoll, through high prairie, low prairie, and salt flat, to swamp. In addition, plantings were made at Colorado Springs, Colorado, and at timber-line on Pike's Peak, and sods were again transferred from Arizona and California to Lincoln. Furthermore, many species were grown isolated in cultivated plots to determine the optimum growth and permit the measurement of competition in the prairie. The development of the plants both below and above ground has been fully studied, and complete records have been kept of the activities of several hundred plants at the various stations, as well as continuous records of the habitat factors. A number of additional subdominants have been added to the list of those grown during previous years. Approximately 1,300 slides have been made of the leaves of 50 or more species grown through the range of climatic and edaphic conditions found in the stations, and it is expected that these will throw additional light on the climatic relations of the grasses in particular.

The results of the experiments of preceding seasons have been tabulated and summarized. During 1920 and 1921 the conditions for plant growth in terms of rainfall, holard, temperature, humidity, and evaporation were most favorable at Nebraska City and Lincoln, intermediate at Phillipsburg, and least favorable at Burlington. Germination and growth at the several stations are summarized in the following table:

Comparison of germination and growth during 1920 and 1921.

1920				1921			
Average germination.		Average establishment.		Average germination.		Average establishment.	
	p. ct.		*p. ct.*		*p. ct.*		*p. ct.*
Nebraska City	93	Nebraska City	67	Lincoln, high prairie	81	Phillipsburg	60
Lincoln, high prairie	86	Lincoln, low prairie	58	Phillipsburg	70	Lincoln, high prairie	54
Phillipsburg	80	Lincoln, high prairie	42	Burlington	43	Burlington	7
Lincoln, low prairie	77	Phillipsburg	33				
Burlington	38	Burlington	25				
Lincoln, gravel knoll	36	Lincoln, gravel knoll	15				

Soil Fauna, by G. W. Goldsmith.

The work has been extended to include typical habitats from the alpine meadows to the plains. A large part of the soil fauna of the alpine meadows is composed of nematodes, which occur most abundantly within 2.5 cm. of the surface. In the warmer and drier soils of the plains this surface layer contains comparatively few forms, the majority being found at a depth of a decimeter or more. The cultivated soils show a similar summer distribution, the greater portion of the animals being found below the layer of cultivation.

The task of checking the efficiency of the methods employed in obtaining the soil organisms has received further attention. At 50° C. the extraction must be continued for at least 24 hours to be complete, when 2 cm. of soil are distributed in three 12-inch funnels. A number of organisms are removed from the soil during the first hour, their reaction apparently being due to temperature. The remaining animals, however, do not behave in the same way and are only removed several hours later upon the drying-out of the soil, evidently in response to drought. No conspicuous group reactions of Acarina, Chilopoda, or Thysanura are noticeable. The time required for extraction is reduced by a smaller amount of soil, by increased temperature, lower water-content, and less compact soil, the most rapid results being obtained with loose, dry duff, the slowest with wet clay.

Climax Formations, by F. E. Clements and E. S. Clements.

The grassland formation has again received the major attention because of its great extent, climatic significance, and economic importance, but much attention has been paid to the three scrub climaxes—desert scrub, sagebrush, and chaparral—and some has been given to montane and subalpine forest. The subclimax prairie was studied from eastern Nebraska to northern Texas, the true prairie in southern Nebraska and northern Kansas, the mixed prairie from Colorado through Wyoming into western Nebraska and through northern and central Texas, the desert plains from western Texas to the edge of the Colorado Desert, and the bunch-grass prairie throughout southern and central California. In the subclimax prairie special attention was devoted to the rank of dominants, the contact with the true prairie, and the climatic relation to the edge of the forest climax. Conclusive evidence of a wide range was obtained to the effect that this association, as its name indicates, occupies a region capable climatically of supporting forest, as is indicated by the fact that the rainfall averages from 35 to 40 inches. In Texas the mixed prairie was found in contact with the subclimax one, the true prairie dropping out in Oklahoma. The overwhelming evidence that short-grass plains are mixed prairie modified by grazing was greatly augmented, all pastures and overgrazed areas in this association being pure buffalo-grass sod in Texas and a mixed sod of this and grama in Colorado and Kansas. *Sporobolus cryptandrus* was found to be one of the chief dominants of both mixed prairie and desert plains, though, like *Stipa,* one of the first to be grazed out by cattle and rodents. The season was especially favorable to the grama grasses, and demonstrated that the desert plain is primarily a *Bouteloua* association, *B. eriopoda* being the most important dominant, followed by *gracilis, hirsuta, racemosa, bromoides, rothrocki,* and *trifida.* The seral relations of the bunch-grass prairie were studied in much detail, and its reconstruction carried toward completion by the discovery of many relict areas along the foothills of the Sierra Nevada.

The desert scrub and sagebrush were traversed in their entirety, the former from southern California to western Texas and the latter from the Sierras to central Wyoming. The upland areas that stretch from trans-Pecos Texas to the Santa Cruz Valley in Arizona are more or less evidently grassland of the desert-plains type, though this fact is often obscured when mesquite, *Yucca*, or *Ephedra* is thickly dotted over it, and especially by excessive grazing or by wind erosion. The valleys of the Pecos, Rio Grande, San Pedro, and Santa Cruz, on the other hand, are covered with what appears to be a typical growth of desert scrub, composed chiefly of *Larrea*, *Flourensia*, and *Prosopis*. In all of these, however, grasses have now been discovered to be the true climatic dominants in all areas protected against overgrazing, such as rights of way, cemeteries, etc., the former regularly being covered with the characteristic grasses through scrub in which these are largely or entirely lacking. As already suggested, climax desert scrub is confined to the regions of the Mohave and Colorado deserts and adjacent Mexico. Similar results have been obtained for the widespread sagebrush of the Great Basin. The climax area, now known to be confined to Utah, Nevada, and adjacent California, was traced in detail during the summer and found to contain grasses only as climatic relics, while the adjoining areas show mixed prairie wherever protection against grazing exists.

Changes in Grassland, by F. E. Clements and E. S. Clements.

The investigation of the changes shown by grassland in response to grazing and climate has been carried on actively throughout the year. All the associations of the grassland climax have had a share in this, though the most striking results have been obtained with the three found in arid climates, namely, mixed prairie, desert plains, and bunch-grass prairie. This is further due to the presence of a scrub community favored by grazing and in California to the presence of aggressive introduced grasses as well. Significant changes due to climate are restricted to the Mohave and Colorado Deserts and to Nevada and Utah, and these are considered in the next section, while the modification arising out of grazing and settlement are considered here. The replacement of grasses by others or by scrub in consequence of grazing takes place in accordance with several well-defined principles. The species that is most eaten yields to one that is less eaten, whether this be a native grass, weedy annual, or a shrub. Tall-grasses give way to short-grasses wherever the two are mixed, since they are most handicapped by grazing. Sod-formers are favored in comparison with bunch-grasses because of their method of propagation and consequent hold on the soil, and sod-formers with runners or stolons, such as the buffalo-grass, tend to replace those that lack them, such as grama. Finally, the grasses of the lowlands are more persistent than those of the uplands because they are coarser and more vigorous and possess a better water-supply, and for this reason grasses often hold out longer in sandy areas if grazing and blowing are not excessive.

Because of sufficient rainfall and the exclusion of grazing as such by cultivation, the subclimax prairies have undergone practically no change. Indeed, the grasses are so vigorous that, once in possession as a result of a dry phase of a major climatic cycle, they have been able to maintain themselves against the climax forest, aided to some extent to-day by cultivation and fire. A somewhat similar condition exists in the true prairie; but the bunch-grasses, *Stipa spartea* and *Kœleria cristata*, have been much reduced in consequence of their habit, early growth in spring, and early flowering, and all the dominants have suffered from the encroachments of the vigorous *Andropogon furcatus* and *Poa pratensis*. Wherever the buffalo-grass occurred in scattered mats, grazing has caused it to become the chief and often the only pasture grass in the western half of the true prairie.

Because of its great extent the mixed prairie has undergone several types of modification. The most widespread of these is its conversion to short-grass, consisting of buffalo-grass and grama, or the former alone, and giving rise to a peculiar community long thought to be climax in character. While the short-grass subclimax thus produced covers thousands of square miles, the tall-grasses, *Agropyrum*, *Stipa*, and *Sporobolus*, are rarely entirely lacking in it, and they usually exhibit their proper value whenever grazing or other conditions permit. No section of this climax is without convincing evidence of its tall-grass members, and the short-grass plains should no longer be regarded as a climax, though it will always need to be taken into account as an outstanding modification of the mixed prairie. The latter has also been greatly changed by the entrance of sagebrush, as well as by mesquite. Where the rainfall has been sufficient to compensate, the grasses have held their own, and a savannah containing much sagebrush results. Elsewhere the grasses disappear largely or completely, and the sagebrush takes on the appearance of a real climax, as in northern Utah, southern Idaho, and eastern Oregon, only to yield in turn to the grasses present when these are afforded protection by fencing. The change wrought by mesquite is less significant, as this rarely becomes sufficiently dense to affect the grasses adversely.

In the warm valleys of southern Arizona and New Mexico the desert-plains grasses have been so completely replaced by desert scrub that the latter has until recently been regarded as the climax. The levels above 3,000 feet are mostly mesquite savannah, but below this the scub appears to be in complete possession. The similarity to sagebrush in several respects led to a comprehensive search for relict grasses and other evidences of change. Each year has increased the list of relict species and areas, while the exceptional grass summer of 1921 yielded convincing evidence as to the structure and extent of the former grassland of the valley at Tucson. The most illuminating discoveries were finding *Bouteloua eriopoda* in 12 relict areas, though it had been known only near the mountains 30 miles to the north and south, and locating the 7 dominant species of *Bouteloua* in a foothill canyon, several of them 40 miles away from any known stations. Perhaps the most satisfactory proof of the former grassland has been afforded by the widespread development of *Bouteloua rothrocki*, *Aristida divaricata*, and *Sporobolus cryptandrus* over the *Larrea* plain during wet summers. Some of the dominants have been traced to the eastern edge of the Colorado Desert in a rainfall of 6 inches, and one or two still persist in sand under a rainfall of 3 inches.

The reconstruction of the original grasslands of the Great Valley and the coastal valleys and hills of California has reached the point where it is possible to recognize the major dominants and their associates, and the rôle of each, to determine their seral relations, and to evaluate the relationship to the similar bunch-grass prairie of Oregon and Washington and to the mixed prairie of northern Arizona. Of 20 dominants, 16 occur in the northern bunch-grass and 12 in the prairies to the southeast. In addition, the southern portion contains 7 relict species that occur abundantly in southern Arizona, 5 of which belong to *Bouteloua.* It seems evident that the grassland of California was originally in contact with the mixed prairie, as the bunch-grass of the Northwest is to-day, and that the climatic change which produced the Mohave and Colorado deserts led to its sharp differentiation. A similar effect is now taking place in the north, where the isolation of the California and Oregon portions of the bunch-grass climax by mountain ranges has already produced an important difference in the major dominants.

The Original Grassland of Mohave and Colorado Deserts, by F. E. Clements.

The comparative study of grasslands in California and Arizona indicated that these must once have been continuous across the Mohave and Colorado Deserts. A special search was consequently made across both areas for relict grasses, and this not only resulted in proof of the assumption, but it also furnished evidence for the probable sequence of climatic and vegetational changes since the Pleistocene. Probably the most significant discovery was that of a well-developed community of *Sporobulus cryptandrus flexuosus, Muhlenbergia porteri,* and *Artistida purpurea* in sandy plains near Goffs and Yucca. These have been able to persist in a rainfall of about 6 inches, since the efficiency of the latter was increased several inches by the sand mulch. The floor of the Mohave with a rainfall of 2 inches is unable to support even the most intense xerophyte among the grasses, the shrubby *Hilaria rigida,* which is found there only in washes and sand. *Eriocoma cuspidata* is nearly as resistant, and this is followed closely by *Stipa speciosa.* At Cabezon, on the western edge of the Colorado Desert, *Stipa speciosa, coronata, setigera* and *eminens, Kœleria cristata,* and *Poa scabrella* suggest the grassland that must have covered much of the two deserts when they had a rainfall of about 10 inches. This is essentially in agreement with the presence of *Hilaria jamesi, Stipa comata,* and *Poa scabrella* in the Argus Mountains at about the same rainfall. The grassland at Kingman, above the eastern edge of the Mohave Desert, with a rainfall of 12 inches, consists of *Bouteloua, eriopoda, Aristida divaricata, Sporobolus strictus, S. c. flexuosus,* and *Hilaria rigida,* while further east at Seligman, with a rainfall of 15 inches, *Bouteloua gracilis, B. racemosus, Andropogon scoparius,* and *Stipa pennata* have appeared also. The significance of this is emphasized by the occurrence of *Bouteloua gracilis, hirsuta, rothricki,* and *bromoides* as relicts at Jamacha, near San Diego, in a similar rainfall. Since grasses are the most important indicators of climatic and vegetational changes in semi-arid and arid regions, it becomes possible to establish a sequence of communities from the absence of grasses in the midst of the Mohave and Colorado Deserts in a rainfall of 2 to 3 inches to mixed prairie under 15 inches at Seligman. This sequence is regarded as indicating the changes by which these regions have passed from mixed-prairie at the close of the Pleistocene to desert at the present under the pressure of shifting climate. It not only seems possible to indicate the successive changes in rainfall and the resulting changes in vegetation but also to obtain a general idea of the time demanded for each. The detailed reconstruction of grassland and climate is in full accord with the conclusions of Merriam as to the former presence of a grazing fauna in the Mohave, and hence of grassland, and those of Buwalda and Thompson as to lakes Mannix, Mohave, and Little Mohave.

The Method and Principle of Relicts, by F. E. Clements.

The investigation of plant formations in the light of the changes effected by climatic cycles has led to the recognition of relict groups and communities as of universal occurrence, and this has been confirmed by the quantitative study of the consequences of grazing. The concomitant study of migration processes has contributed to the mass of evidence that effective migration at a distance is limited to carriage by water and by man and his domestic animals, and that practically all extra-areal groups are to be regarded as relicts of a former greater extension. Corroboration of this is furnished by the current studies in experimental vegetation, which show that plants once established can persist in the face of conditions that make their ecesis absolutely impossible. Apart from grazing and physical conditions, competition is such a vital factor in establishment that disturbance or climatic change is almost universally a prerequisite to successful establishment. During the intensive field work of the past 10 years, no case has been found of effective distant migration other than by man and water. Even in the case of fleshy fruits with exceptionally well-protected seed, such as the cedar, migration is practically always local.

While forest and scrub have received much attention, this has been centered on grassland, because of its peculiar climatic value and its ready response to grazing. Forest relicts have been produced by fire, lumbering, and cultivation, and grassland relicts chiefly by grazing, though cultivation has been the chief factor in the subclimax and true prairies. Under the serious overgrazing widespread in the West, grasses have been able to persist only under protection of some sort. This consists regularly of fencing, but it may be afforded by a greater water-content, as in sand, valleys, and rocky slopes, or by the steepness or exposure of the slope itself. Wet years invariably bring into view grasses that have been persisting in a suppressed condition. Competition on the part of weeds is a potent factor in destroying grassland, and often the slightest barrier to the movement of weed-seeds will enable grasses to persist. The best of all relict areas are railroad rights of way, followed by fenced roadways, fenceways, cemeteries not sown to grass, hay-fields, rock ridges, north slopes, sandy areas, depressions, and ditch edges. A fenced roadway between two fields exhibits distinct differences with respect to protection, water-content, and disturbance, and its analysis into field strip, fence strip, road strip, ditch edge, and road edge has revealed a fairly definite scale of adjustment to various sets of conditions. Species differ greatly in their response to these, and hence serve as delicate indicators of processes and changes no longer in evidence otherwise.

Succession in Inland Dunes and Sandhills, by F. E. Clements.

In connection with the developmental study of the climaxes of the West, the seres of dunes and sandhills have been under investigation since 1914. During this time the large majority of inland dune and sandhill areas from Nebraska to California have been visited, some of them several times, and some comparative studies have been made on the dunes of the California coast. Most of the areas concerned lie within the grassland climax, but dune areas of importance occur also within the sagebrush and desert-scrub climaxes. During the present season such areas have been visited in the Colorado Desert, near Fallon, Nevada, in eastern Colorado and southern Nebraska, at Eufaula, Oklahoma, at Burkburnett and Quanah on the Red River, at Odessa and El Paso, Texas, and at Deming, New Mexico. While the early stages of all the areas studied have much in common, they naturally diverge more and more as the various climaxes are approached. In some cases at least the formation of dunes appears to be related to climatic cycles, and an attempt is now being made to correlate this with other cyclic phenomena.

Permanent Quadrats and Tristats, by F. E. Clements, E. S. Clements, and J. V. G. Loftfield.

In addition to maintaining the quadrats, transects, and tristats already installed, a considerable number of new ones has been established. The Hill pantograph and the methods of charting and record have been further improved and a new unit for volume measures has been devised. This is termed a *cubon;* it is designed to permit the counting or charting of organisms in unit volumes of the soil or the air and, to a certain degree, in water. The community chart has been further developed and modified to serve a variety of purposes. The quadrat has been adapted to life-history studies by means of charting at intervals of 2 weeks or a month during the growing season and at longer intervals between. This permits a record of the growth and spread of the plant from the appearance of the seedling or shoot through flowering and fruiting to the time of its disappearance or entrance into the resting period. The overhead method of quadrating by means of the camera has been perfected, and it is being employed in the field to determine the different uses to which it can be profitably put. It is thought that it can be combined with the tristat to give a complete picture of the structure and setting of any part of a plant community. The development of quantitative measures of vegetation has been rapid during the past 5 years, and it is planned to make the new methods available to working ecologists, together with some account of the results to be obtained by their use.

Grazing Research, by F. E. Clements and J. V. G. Loftfield.

In addition to the usual field work on overgrazing, carrying capacity, indicators, and the effect of climatic cycles on the growth and composition of grasslands, the projects at the 3 cooperative stations have been considerably expanded. At the Santa Rita station, 24 new seedling quadrats, 3 additional burn quadrats, and 5 special quadrats have been installed, in addition to transects for determining the effect of clearing off scrub upon the behavior of the grasses. The relation of burning to composition and growth is being followed in communities of native grass, in scrub and savannah, and in weedy associes. Three factor stations have been installed in the reserve for a complete study of the physical factors in the different grass communities. The inclosures in northern Arizona have been studied in much greater detail, and new stations have been established at Kingman and at Prescott. In addition to the isolation transect already established at the Sonora substation in western Texas, in cooperation with the Texas Experiment Station, 2 new exclosures have been installed to show the effect of resting the grass for the four different seasons of the year, as well as successive years. A considerable number of quadrats was located within and without the exclosures, and it is expected to chart these twice a year until the major facts are established.

Destruction of the Range by Prairie-dogs, by W. P. Taylor and J. V. G. Loftfield.

Experimental exclosures were installed in three representative areas of northern Arizona in 1918 through cooperation with the Biological Survey of the United States Department of Agriculture. While these were designed to serve several purposes, the most important was to determine the effect of the food-habits of the prairie-dog of the region (*Cynomys gunnisoni zuniensis*) upon the carrying capacity and composition of the range. The latter is a portion of the mixed-prairie association, usually modified in this region by the suppression of the tall-grasses through overgrazing. The northern area lies in Coconino Wash, about 9 miles south of the Grand Canyon, and consists of *Agropyrum glaucum* and *Sporobolus cryptandrus*, with small amounts of *Bouteloua gracilis*, *Stipa comata*, and other grasses. The exclosure consists of two equal parts, proof against both cattle and rodents, but with one containing a group of prairie-dogs, and it lies beside an unfenced area provided with quadrats also. This series has permitted a quantitative study of the vegetation under three conditions: (1) under total protection, (2) grazed by cattle alone, and (3) grazed by a known number of prairie-dogs. Similar exclosures are located at Williams and at Seligman, the former in a community of *Bouteloua gracilis* and *Muhlenbergia gracillima*, the latter in one of *B. gracilis* and *eriopoda*.

The growth of the grasses under the three conditions has been measured by means of clip quadrats, and at the Coconino Station has yielded the following figures, expressed as grams of forage per square meter:

	Agropyrum glaucum.			Sporobolus cryptandrus.			Total quantity of grass.		
	1919.	1920.	1921.	1919.	1920.	1921.	1919.	1920.	1921.
Total protection.	100.0	117.1	138.8	164.6	32.8	81.9	264.6	149.9	220.7
Rodent grazing .	36.8	24.3	22.6	Trace.	None	None	36.8	24.3	22.6
Cattle grazing . .	6.6	8.7	6.7	4.6	None	6.4	11.2	8.7	13.1

Agropyrum glaucum shows a consistent increase for the three years of total protection, probably owing to its better utilization of rainfall as a result of its sod habit. As a bunch-grass, *Sporobolus cryptandrus* appears to be more dependent upon the seasonal distribution of the rainfall, and it is also unable to hold its own in competition with the increasing *Agropyrum*. Rodents are especially fond of it, as are cattle also; but while the latter merely graze it to the ground, the prairie-dogs destroy it completely by the second year.

Climatic Cycles and Tree Growth, by A. E. Douglass.

The study of the record of the sun-spot cycle in *Sequoia* has been extended and two important principles brought to light. The first is that the effect of the sun-spot cycle on growth depends upon topography, the basin trees only occasionally showing the 11-year period or its multiples, which are conspicuous in upland trunks. The second principle involves the correspondence of ring cycles in trees several hundred miles apart, showing them to be real and climatic in origin. An endeavor is being made to fill out a series of tree sections that will represent the region from northern Colorado to the Mexican boundary and from western Kansas to the Pacific. A considerable number of buried logs has been secured from the Flagstaff region, in which a perfect cross-identification has been found between two widely separated trunks, thus increasing the chance of determining their age by comparison with sequoia. The cycles from beams in the ruins at Aztec have been minutely compared with those of the sequoia, partly in the hope of disclosing the date when the beams were cut and partly to furnish further evidence of the value and reliability of cycles. Fine sequences of rings have been discovered in the Egyptian coffins of the Metropolitan Museum, and other objects of wood yielded excellent rings of various dates, such as B. C. 2600, 1950, 1400, etc. The cross-identification of beams from prehistoric pueblos by means of the annual rings has progressed to the point where a museum beam labeled "Pueblo Bonito" was shown to have come from the ruins at Peñasco, and it has now become so certain that a new method in prehistoric chronology is available.

Rainfall and Climatic Cycles, by F. E. Clements.

A preliminary investigation of rainfall cycles has shown a definite relation between drought periods and sun-spot maxima, every maximum of more than half the greatest annual sun-spot number coinciding with general and critical drought in the western United States. A comprehensive analysis is being made of all rainfall records of 20 years or more for the western United States and Canada with reference to sun-spot minima and excess rainfall, the 2 to 3 year cycle, the seasonal and monthly balance, and crop production. The principle of the excess-deficit balance has been applied in all of these and reveals within the 11-year cycle a general if not universal grouping of plus and minus years into cycles of 2 to 3 years, shown not only by the various stations but also by the State averages. In many cases these short cycles seem to be related to the drought periods occurring at the sun-spot maximum, while in others no such connection is evident. Critical drought periods are regularly preceded or followed by years of high or exceptional rainfall, and this excess-deficit relation is also characteristic of the short cycles, though the amplitude is naturally smaller. In seeking the causes of this balance it seems probable that it is an expression of the physical law of action and reaction, though this may be exerted primarily through the sun-spot cycle. It is possible that the short cycles may be due to the reciprocal relation of precipitation on the one hand and evaporation-transpiration on the other, and that the water-loss from plants may be a decisive factor in this at a short distance from the ocean. Particular consideration is being given to the rainfall of the Colorado Basin, in the hope that the sun-spot cycle and the principle of the excess-deficit balance will make it possible to anticipate the major variations in rainfall and to base the use of irrigation water upon some knowledge of what will be available. The fact that the rainfall of a region will be three or four times greater at the maximum than at the minimum makes it evident that reclamation systems should be organized upon an expansion-contraction basis and should provide for subsidiary reservoirs in the middle and upper portions of a basin to store flood-waters against a drought and thus insure a constant and equable supply.

Principles and Methods of Bio-ecology, by F. E. Clements, C. T. Vorhies, and W. P. Taylor.

The concept of the biome was advanced in 1915 to emphasize the importance of treating plants and animals together as mutually interacting members of a community and hence of recognizing that plants must constitute the basis of the different units, both climax and successional. This concept has been tested during the succeeding years of field study, and the entire field of bio-ecology has been sketched in outline to serve as a guide for further work. The principles and methods involved in the relation of both individual and community to the habitat, as well as of plants and animals to themselves and to each other, have been analyzed in detail. During July and August field studies in bio-ecology were made in the Sierra Nevada of California on the line of the transect established for transplant and other experimental work. The stations included Mather and Aspen Valley in the montane forest climax, Porcupine Flat and Tuolumne Meadows in the subalpine forest climax, and Benton, Mono County, in the sagebrush climax. Further studies were made to determine whether animals fall properly into communities of which plants form the basis, to define more accurately the correlations between plants and animals, to adapt and refine census methods, and to extend the knowledge of bird and mammal life-histories. Various methods, especially those of plant ecology, were subjected to field test in order to determine their fitness for quantitative work with birds and mammals. Additional evidence was obtained to show that the biome is a basic concept, indispensable to the causal and developmental study of biotic communities, and that the climaxes and seres found in vegetation constitute the groundwork in which animals find their proper place. The summer's investigations emphasized the great need of definite and quantitative correlations between plants and animals, as well as the need for ecological life-histories that will take into account the factors of the habitat, the reactions of the organisms, and their respective rôles in the community.

Biotic Succession in Bad Lands, by F. E. Clements.

As usual, a considerable number of bad-land areas have been visited during the year. These ranged in time from the Permian to the Pleistocene and in extent from the Red River to the Pacific. The chief areas were the Wasatch, Green River, Bridger, and Uinta of northeastern Utah and southwestern Wyoming, the Cretaceous Mancos and Steele of the same region, and the Oligocene and Miocene of western Nebraska and eastern Wyoming. The Permian "breaks" of the Great Plains were seen from the Red River to the Edwards Plateau in Texas, and the Miocene bad lands of the Pacific Coast were studied in San Timoteo Canyon and at Del Mar. Further evidence was secured to indicate that the erosion cycles of Bad Lands are an effect of climatic cycles and that they are in accord with other consequences of climatic changes in the West.

The first studies of succession in Bad Lands were made in 1897, and the investigation has been carried on actively since 1913. It is expected that the field work will be completed in another season, and as a consequence increasing attention is being given to utilizing the results as a further basis for the organization of the new field of paleo-ecology. This has involved the refinement of the plant materials, the elaboration of the concept of climatic cycles, the reconstruction of the climaxes and seres of the past, and a special consideration of present and past processes in sedimentation and their relation to climate and vegetation.

Researches in Sedimentation, by F. E. Clements and R. W. Chaney.

Further studies of present-day deposition and erosion have been made in connection with succession in bad lands, dunes, playas, valleys, etc., and the nature and significance of sedimentation in the past have again received special attention in bad-land and sandhill areas. A large number of suggestive leads were secured and various working hypotheses tested by a reconnaissance through the Uinta, Bridger, and Green River of Utah and Wyoming, made in company with Dr. W. D. Matthew, and one through the Miocene and Oligocene of western Nebraska, made under the leadership of Mr. Harold J. Cook. These afforded a unique opportunity to compare views and interpretations and to refine the evidence from the various fields of approach. They threw into clear relief the necessity for a cooperative attack upon the problems of paleo-ecology, and emphasized the urgent need of detailed and quantitative studies of sedimentation in different horizons, in close connection with similar work on present sediments. While it is obvious that there is no real distinction between present and past sediments, it has proved helpful at least to distinguish those in the actual process of formation to-day from those formed recently and the latter from deposits laid down in the Pleistocene or earlier. While the actual details of sedimentation can be studied only in the first, their significance for the interpretation of fossil sediments often depends in large measure upon an understanding of the second. In the case of eolian deposit it has proved possible to obtain a complete series from dunes still forming, to sandhills and sand-plains that have become finally stabilized, and to assign these relative dates. Similar results are indicated for playa and stream deposits, though it has come to be recognized that a river system of to-day exhibits practically all types of deposition in semi-arid regions and that this must have been true throughout the Tertiary.

Because of its relation to playa deposit, a particular study has been made of the formation of caliche in the valley soils of the Southwest. This has been supposed to be due to the upward movement of lime-bearing water in consequence of evaporation, but in a number of localities at least the caliche of the upper 5 feet or so was evidently deposited in the pools of a playa. The lime crusts not only follow the contour of the bottom and sides, but they are also fine-grained, almost pure, and polished on the upper surface, while below they grade into the coarse material of the detrital layer brought in during the floods of a wet phase of the climatic cycle.

Research in Hay-Fever.

Pacific Coast and Great Basin: H. M. Hall.

Studies of the hay-fever plants of these two regions have led to certain definite conclusions as to the species responsible, and hence to the kinds of pollens to be used in the treatment of this malady. Several fundamental principles have been confirmed or established, such as the negligible importance of insect-borne pollens, the relatively high virulence of certain groups of plants, and the varying constitution of the hay-fever flora in different regions. It follows from this that pollen extracts very useful in the East or in Europe may have little or no value for the treatment of cases in the West, where for the most part the flora is very different. On account of this, as well as the large number of causative species in the Great Basin and Pacific States, it becomes necessary to make detailed hay-fever surveys for each district. This permits the preparation of lists of the principal hay-fever plants, in which is given the period of pollen production, the relative importance, and the results obtained from the testing of patients by specialists. Such lists have now been prepared for 12 western districts, and the typewritten copies are in use by practicing specialists, who have supplied much valuable information as to the results obtained.

These studies were first undertaken in cooperation with Dr. Grant Selfridge, of San Francisco, and other specialists now cooperating in the work are Dr. A. H. Rowe, of Oakland, and Dr. George Piness, of Los Angeles, Dr. T. C. Chamberlain, of Portland, and Dr. Wm. Scheppegell, of New Orleans. At the University of California, Dr. Legge and Dr. McVey are assembling a large collection of pollens to be used in a cooperative study of the causes and treatment of hay-fever among university students. The frequent requests for lists of hay-fever plants and for assistance in procuring pollens, which come from physicians and specialists of nearly every Western State, indicate the demand for information on this subject, and the need of a thorough scientific investigation of the underlying principles of pollen therapy. A hay-fever survey of California, with special lists for three of the more densely populated districts, has been prepared at the request of the United States Public Health Service and published in its reports during the year. Similar surveys for other States are under way and will be issued as soon as they are completed.

Rocky Mountain and Mississippi Valley Regions: F. E. Clements, W. V. Mullin, and R. W. Gilmore.

A similarly comprehensive investigation of the causes, diagnosis, treatment, and prevention of hay-fever has been undertaken in the regions indicated. While the emphasis has been placed upon diagnosis and therapy, special studies have been made of the production, distribution, and collection of pollen and the occurrrence, abundance, and eradication of hay-fever plants. In order to make a knowledge of the latter and their pollens accessible to physician and patient alike, a manual is in preparation which will illustrate all the important species and pollens by means of color-plates. The amount of pollen produced, the time of day when it is shed, and the curve of production during the flowering season for a particular species have been investigated and a chart devised to show the beginning, maximum, and close of pollen production for each of the important species of a definite region. The occurrence and abundance of hay-fever species in and about Colorado Springs have been recorded in detail, and it is proposed to map these as a further guide to diagnosis. The distribution of pollen has been studied under varying conditions and surroundings in different parts of the city, and improved methods have been developed for collecting, sifting, and preserving pollen and preparing pollen extracts. At the same time an energetic campaign has been waged to secure the cutting of the weeds of vacant lots, streets, and alleys, with the discovery that successive mowings are necessary to prevent regeneration sufficient to prolong the period of flowering, although the total pollen production is greatly decreased.

A special endeavor has been made to render methods of diagnosis more direct and accurate. In addition to the map of distribution and the chart of seasonal production, a method of local diagnosis has been developed by means of a survey of the immediate neighborhood of the patient and of the regular use of pollen slides for catching the pollens concerned. With the aid of the history of each case, this usually discloses the offending pollen at once, or narrows the choice of extracts for the intradermal test to two or three at most. With respect to the action of specific pollens, 7 species and varieties of *Artemisia*, which comprise the sagebrushes and sageworts, and several related genera of the ragweed and lamb's quarters groups, are being made the subject of a special research. In Colorado the sageworts have been found to be much more important than the ragweeds, Russian thistle and lamb's-quarters have proved much more virulent than in the East, and a new plant, the summer cypress (*Kochia scoparia*), has been added to the list of important causative species. This is especially significant, as this species is widely planted in gardens for hedges.

BOTANY.

Britton, N. L., and J. N. Rose, U. S. National Museum, Washington, D. C. *Studies of the Cactaceæ.* (For previous reports see Year Books Nos. 11–16, 20.)

The cactus project is being brought to a close. Our time during the past year has been spent on volumes 3 and 4. Volume 3 was issued October 12, 1922, and consists of 255 pages, 24 plates, and 250 text-figures. Volumes 1 and 2, previously published, were issued June 21, 1919, and September 9, 1920, respectively. The manuscript for volume 4 contains about 1,000 pages, 37 plates, and about 250 text-figures.

Interest in the cactus family has greatly increased recently. In Europe there is almost a cactus craze and dealers and cactus fanciers are anxious to obtain seeds and plants. Some horticulturists are making a speciality of this family and new additions of popular cactus works are being brought out. The interest in Holland is very strong and a catalogue of all the cactus names, based on this monograph, is being prepared there. The larger botanical institutions are building up their cactus display collections and at least one of our American collectors has been engaged to ship cacti from all over Mexico for the next two years.

GEOLOGY.

Chamberlin, T. C., University of Chicago, Chicago, Illinois. *Study of fundamental problems of geology.* (For previous reports see Year Books Nos. 2–20.)

As indicated in the last report, these studies are being guided by general conclusions quite notably at variance with inherited tenets relative to the physical constitution of the earth. These guiding views have been derived in part from previous geologic and cosmologic studies, but in a very notable degree also from the disclosures of recent physical and chemical researches relative to the constitution of matter. It will be conceded, no doubt, that reconstruction of geologic interpretations, so far as to bring them into harmony with the fundamental nature of matter, at least, is imperative. The mere acceptance of the new tenets, however, is only a small part of the reconstructive task; the larger labor lies in the revision of the various derivative doctrines into which erroneous basal views have entered more or less occultly. It is not at once apparent how many current doctrines are dependent ulteriorly on the basal concepts that are now found untenable; nor is it always obvious what are the special applications of the new basal views which should replace them. This makes special emphasis of the salient features of the new views, when they enter a discussion, permissible if not obligatory. Among the basal conclusions that have entered into these studies during the past year are the following:

1. That the earth-body is essentially an elastico-rigid spheroid in which the molten and viscous elements are so far subordinate that the larger problems of the earth-body are to be solved on the elastico-rigid basis.

2. That the method of yield of the elastico-rigid body is dominantly *idioatomic*, or *idiomolecular*, that is, takes the form of progressive reorganization atom by atom or molecule by molecule, each acting individually and successively rather than collectively and simultaneously as in fluid or viscous bodies.

3. That the energy engaged in organizing and maintaining the elastico-rigid mechanisms of the earth-matter is vastly greater than the energy engaged in producing fluidal or viscous relations between these elemental mechanisms, or, in other words, the revolutional energy in the earth is vastly greater than the vibratory energy.

4. That both the rigidity and the elasticity of the elemental mechanisms, whether atoms or molecules, is essentially dependent on the intense revolutions of the electric elements and the magnetic polarities that arise from these revolutions.

5. That the atoms and molecules are themselves elastico-rigid bodies and probably the supreme type of such bodies.

6. That the intimate structure of the earth has a minute openness of the planetary order and a practically indefinite compressibility.

7. That the earth's resistance to compression, as also its rigidity and elasticity, are dynamic (gyroscopic) rather than material in the common sense of this term.

8. That the main heat of the interior is a *product* of the earth's own concentrating, combining, and organizing processes, especially its compression, and

is hence subordinate to them and subject to their partitive actions. The view that the heat of the earth is mainly an *inheritance* which *dominates* and *restrains* these processes has been abandoned.

9. That the state of the interior of the earth as a whole is elasticostatic rather than hydrostatic, but that the idiomolecular readjustments to differential stresses tend constantly to bring the elasticostatic condition into coincidence with the corresponding hydrostatic condition, but a residual divergence has always been present as far back as geologic evidences go.

The studies of the year have involved all these propositions in greater or less degree and have greatly strengthened the considerations on which they rest, but only a few of these supplemental considerations need be formally reported. Respecting the controlling place assigned the elastico-rigid state, it is to be noted that some students of the subject have felt that, while the distortional phase of the seismic vibrations traversing the earth, taken in connection with the nutational oscillations and the prompt responses of the earth-body to tidal deformation, leave little room to question the simple fact of the elastic rigidity of the earth, yet room is left for doubt as to the effective value of this property when long-continued stresses are experienced, because the direct demonstrations of the elastic rigidity relate only to short stresses. The studies of the year, however, show that this source of doubt is practically covered by the actual phenomena, so that it is only applicable to hypothetical cases. The evidence lies chiefly in two very significant facts: (1) When the elastic limit of deep-lying matter is reached and a new state is inevitable, this new state is most commonly *a new elastico-rigid state*, so assumed as to relieve the enforcing stress. This is particularly the case when the balanced pressures are high and the differential stresses come slowly into action. (2) The simple fact that the elastico-rigid state *actually exists* under practically the whole range of pressures, temperatures, differential stresses, and time effects now being brought to bear on the various parts of the outer seven-eighths of the earth, at least, as shown by the transmission of the distortional seismic waves, is concrete evidence of the wide persistence and efficiency of this state. The effective coöperation of the first of these features in securing the second is favored by the slowness of the increase of the great stresses that affect the depths of the earth-body.

Respecting the first, it may be observed that the elastico-rigid state is in itself *a yield provision of a specific kind.* Its normal action under stress is partitative. Half the stress is converted into strain which balances the remaining stress; the energy thus becoming "latent." This constitutes the elastic phase of the yield provision and is efficient up to the elastic limit, beyond which the yield takes on a new phase, the existing elastico-rigid state breaking down. It seems to have been assumed, without explicit consideration, that this new phase *must be other than elastico-rigid,* since it follows the breakdown of the previously existing elastico-rigid state and since crushing, shearing, or liquefaction are the common sequences in experimental work under surface conditions. But glacial and metamorphic phenomena show that even at relatively shallow depths of the earth, the previous elastico-rigid state is followed by a new elastico-rigid state that is accommodated to the excess of the existing stress and relieves it, and, further, is generally capable of sustaining a higher stress than the previous state of like kind. This transition to a new state of like kind is not universally true, especially when yield by crushing, shear, or melting is readily available by reason of low resistance in some one or more directions, as is commonly the case at and near the surface, but as depth augments the balanced stresses and distributes more evenly the differential stresses, such a succession of like kind seems to become increasingly true. From the particular elastico-rigid state that is overstressed and forced to give way, the transition to a new state of like kind seems to take place by the individual detachment of such particular atoms or molecules as are situated so as to bear the most intense stress or to be held by the fewest bonds (as at angles or on sharp curves) and by the transfer of these detached atoms or molecules—perhaps their projection—to new points of attachment where the stresses are less, or more bonds or stronger bonds are available; in other words, the action is idioatomic or idiomolecular. This is not gaseous or liquid action in the strict sense of these terms, for gases and liquids are assemblages, while this action is individual. There may, of course, also be gaseous and liquid action. The general assumption, therefore, that when an elastico-rigid body yields to stress it is by crushing, shear, or liquefaction, is true only under some conditions, not under all. Such methods of yield are common under surficial and some sub-surficial conditions. They are also prevalent when contacts favor solution, or when high temperature and low pressure favor melting, but the more prevalent method in the depths seems to take the form of readjustments and reorganizations of the type exemplified by glacial motion and rock "flowage."

Now, having in mind this doubly adaptive mode of yielding (yielding first by the elastic partition of the stress into balanced stress and strain, and later, when necessary, by transformation into a new elastico-rigid state by progressive atomic or molecular action), it is easy to understand the second very significant fact, the actual elastico-rigid state of the earth in portions subjected to very different combinations of balanced and differential stresses, of different temperatures, and of such effects of time as are inheritable from the previous geologic ages. It is to be noted that the distortional seismic waves serve as a very searching agency. They test the nature of every part of the earth through which they succeed in passing. They therefore show that a highly rigid elastic state prevails very generally, if not intimately, throughout the outer seven-eighths of the earth at least, in spite of the different temperatures, pressures, differential stresses, time effects, and other coöperating agencies that now exist or are represented by transmitted effects. Some interstitial liquid matter and some molten pockets are of course to be recognized. The portions shown to be elastico-rigid vary greatly in their conditions and show the compatibility of the elastico-rigid state with such variations and their combinations. In the light of what was said in the preceding paragraph there seems no reason to suppose that any other probable variations would prove incompatible.

This combination covers essentially the whole ground of present geologic action—except the subordinate states already recognized. It therefore does not seem necessary to consider imaginary possibilities.

The studies of the year have developed another very significant feature of the problem of internal conditions. It is a well-known fact that rigidity and elasticity increase as depth and pressure increase, notwithstanding the rise of temperature. This is shown by the increased velocity of the seismic waves, both distortional and compressional. But the rate of this increase of velocity falls off and practically ceases near the mid-depths. This has been interpreted as implying a change from the elastico-rigid state to a viscous or some other non-rigid state. But in drawing this inference the important factor of increasing density seems to have been overlooked. Density tends to decrease wave velocity, and hence to secure the velocity to be used in comparisons of the elastico-rigid states, correction must be made for this increasing density. When the observed velocities are thus corrected by the use of the Laplacian law of density, or better still by the Roche formula which was devised especially to meet the astronomical requirements, a continued increase of rigidity and elasticity is indicated, though it is not so rapid an increase as that in the lesser depths. There is probably a progressive change in the material of the earth as held by Oldham.

This correction brings the testimony of the seismic waves into general harmony with the evidences of the body tides and the nutational oscillations, both of which indicate that the earth as a whole is not only rigid and elastic but that the mean rigidity and elasticity is much greater than that near the surface.

It has been noted that seismic waves of both distortional and compressional types grow progressively imperfect as they penetrate to greater and greater depths and distances, until finally they cease to give readable records before the diameter of the earth is penetrated. This growing debility is a feature of both sorts of waves. This implies that a common source of debility affects both sorts of waves—doubtless the natural destructive and dispersive effect of the increased penetration of an imperfect medium. As a rule, the records of the distortional waves become illegible with less penetration than the compressional waves, but this is not at variance with what might be expected, for the compressional waves move about 50 per cent faster than the distortional waves, a fact implying that they are actuated by a more effective elasticity, elasticity of volume, the distortional waves being actuated by elasticity of form. This difference in dying-out does not, therefore, seem to warrant the inference that a viscous state replaces the elastico-rigid state. To justify that, there should be a rather sudden cessation of the distortional waves, while the compressional waves should continue to penetrate the greater depths and distance even to the diameter, and give good records. Besides, as already noted, the testimony of the velocities, when corrected, implies continued rigidity, as do also the independent evidences from the body tides and from the earth's nutation.

These several supplementary considerations seem to greatly strengthen the conclusion that the body of the earth is essentially elastico-rigid. The ground for doubt about even the most central portion seems to be vanishing.

In the course of the year's studies some new computations, based on independent ground, were made respecting the preponderance of the organizing revolutional energies within the earth over the dissipative vibratory energies. These gave results of the same high order of preponderance as the previous ones. Some of the assumptions, however, are necessarily quite uncertain, and it is scarcely worth while as yet to assume that the results are very close to the true ratio.

THE PROBLEMS OF THE OCEAN.

It has been evident for some years that the inherited interpretations of the ocean and of its saline contents need fundamental reconsideration in the light of advances in related lines of inquiry. Since the ocean is regarded as, in some special sense, a residual product of the action of the atmosphere and its precipitates on the lithosphere, it is not unnatural that the ocean should be the last to be reached in the application of the revolutionary results of chemical and physical as well as geological and cosmological researches. The most outstanding and tangible of the incongruities in the interpretation of the oceanic solutions lies in the extraordinarily high proportion of oceanic chlorine to oceanic sodium on the assumption commonly made that both are mainly derived directly from the decomposition of the "crust" of the earth. This incongruity is the more remarkable because chlorine and sodium are the leading constituents of the oceanic salinity, and form, by their simple union, the most common of the oceanic salts. In the igneous rocks of the crust the average content of chlorine, according to the latest compilations of Clarke and Washington,[1] is 0.096, while that of sodium is 2.83. But in the ocean the proportions are about 1.8 chlorine to 1 sodium. On the assumption that the proportions of chlorine to sodium in the ocean should be essentially those in the parent rocks, the discrepancy is of the order of 50 to 1. Now, since it will only increase the incongruity to suppose that chlorine and its compounds lack solubility or that by recombination chlorine goes back into a solid state after entering the ocean, the whole burden of removing the discrepancy is to be sought in some modification of the interpretation of the action of the sodium. With certain exceptions to be mentioned presently, it has been commonly held that sodium does not systematically recombine with the sea-sediments in any appreciable degree and thus habitually return to the solid state as a constituent of the sea-deposits. It is recognized that potassium, calcium, and magnesium, the most common alkaline associates of sodium, do thus return to the solid state as constituents of the marine shales, limestones, and dolomites, but, except in negligible amount, it has been affirmed that this is not true of the sodium, because of the higher solubility of its compounds. Estimates of the age of the ocean have been based on the persistent accumulation of the sodium thus postulated and these have been widely accepted. It has, indeed, been recognized that winds blowing from the sea to the land carry back sea-salts, and allowances have been made for the repeated reckoning of these as though derivatives from disintegration. So, also, it has been recognized that sea-salts are entrapped in the pores of marine sediments and that later these are sometimes raised above the sea-level and drained into the streams and so re-counted; allowances have been made for these duplications. So also, allowance has been made for salt-deposits embraced in the sedimentary deposits. But when allowances have been made for all these, the accounts of sodium and of chlorine fall far short of balancing. Some further mitigation of the discrepancy has been found in the supposition that a part of the chlorine came from volcanic gases rather than the decomposition of the surface rocks, but to assume that the amount of this is sufficient to match the unchlorinized sodium carried down by the streams seems to be greatly overstraining the evidence. Besides, recent investigations do not fully support the earlier views of a large prevalent chlorine content in the volcanic gases.[1]

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[1] Frank W. Clarke and Henry S. Washington, U. S. Geol. Surv., and Geophys. Lab. Carnegie Inst. Wash., The average composition of the igneous rocks, Proc. Nat. Acad. Sci., vol. 8, No. 3 (May 1922).

In addition to these and other concrete difficulties connected with the inherited interpretation, the theory on which it is based is itself unsatisfactory. Under modern chemico-physical views mass action, degrees of concentration, influences of ingredients on one another, the laws of equilibrium, etc., play large parts in the interaction of the mingled constituents at all stages of the complicated processes of disintegration and solution on land, of separation and mixture in transit to sea, and of recommingling in the ocean. Theoretically, each individual constituent should play its own part in its own way and at its own rate and proportion at all stages of its history, dependent merely on its own contacts and instantaneous conditions. Theory recognizes no exception.

Besides, looking at the problem from the larger historical point of view, the kinetic laws of molecular action and the limitations of the earth's power of gravitative control imply that the accumulation of the ocean must have been more prolonged than has been assumed in the inherited view. If so, it is almost inevitable that the internal reactions were proportionately more important than they have commonly been thought to be. An attempt was therefore made to find the source of the seeming discrepancy between the oceanic chlorine and sodium in accordance with revised chemico-physical as well as geo-cosmological tenets. The line of effort was a rescrutiny of the natural processes of decomposition, transport, and recombinaton, to see if some systematic return of the sodium of the ocean to the solid state in the ocean sediments had not been overlooked or too lightly emphasized, for it is obvious that if sodium thus returns in sufficient proportions, the apparent discrepancy disappears.

In following the course of sodium and its associated elements, from the rocks to the soils and soil waters, from these to the streams, through the streams to the ocean, and through the recombinations that attend the mingling of the fresh waters with the salt waters of the ocean, it appeared (1) that the sodium was separated from the acid radicals with which it had been united in the rocks and soils more freely than was the potassium, calcium, and magnesium, as has long been recognized and emphasized; (2) that the basic radicals so formed were carried to the ocean as true solutions and were the chief elements analyzed, and so constitute the contribution to the salts of the ocean chiefly taken into account in studies on the subject; but (3) that, in consequence, the acid radicals were concentrated in the surface soils and formed their largest portion, until (4) later they were also carried, chiefly at flood stages, to the ocean, not as true solutions but as colloids or as silts, clays, and sands, and (5) that on entering the sea these acid radicals came again into contact with basic radicals of the same sorts as those with which they had been united in the rocks and soils. But (6) the basic radicals had been separated from the acid radicals under conditions of *very low concentration* because of the abundant meteoric waters that passed through the soils; while in the ocean, on the other hand, (7) they were in *a much more concentrated state*. Under these new ratios of concentration, (8) *the acid radicals reunited with the basic*

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[1] W. T. Allen, Chemical aspects of vulcanism with a collection of the analyses of volcanic gases, Papers from the Geophysical Laboratory, Carnegie Inst. Wash. Pub. No. 440 (1922).

radicals in equilibrium proportions suited to these new states of concentration and to their own inherent properties. Now, it is to be noted that the concentration of the sodium solutions in the ocean was much higher than that of the potassium and the other alkalies and that this led to *a relatively high reunion of sodium with the acid radicals.* There is abundant evidence in the analytical experiments of agricultural and other technical chemists that such partitive reversing reactions take place. Such action is also indicated by ancient domestic practices of rendering sea-water fresh enough for drinking purposes by passing it through soils. The acid radicals are largely carried down with storm-waters or the freshets from snow thaws; they form the turbid factor of these waters, and so are naturally enough neglected in analyses made for agricultural or domestic purposes. The account of what the streams carry to the ocean is thus one-sided and radically defective. The reaction between the turbid acidic matter and the sea-solutions undoubtedly takes place chiefly at the contact of the relatively light turbid waters with the heavier sea-waters, over which they spread out in fan-like form at the mouths of streams. In such a situation, a transient partial recomposition of sodium and the acid radicals would easily escape detection if not diligently sought, while such sodium silicates as are found in sediments taken from the ocean-bottom have been plausibly assigned to incomplete decomposition on land. The recombination of the sodium with acid radicals, even when aided by concentration, will not equal the combinations of potassium with the acid radicals, but the partial recombination of the sodium should be systematic and persistent until it reaches its proper equilibrium value. The assigned products of such reunion are chiefly silicates of aluminum, iron, and sodium, and are commonly found in marine muds and shales. These recombination products, mingling with the sediments at the bottom of the ocean, are not readily distinguishable from similar compounds that have been interpreted as undecomposed residues of the disintegrating processes on the land or as the wind-blown products of eolian abrasion. The importance of the problem invites special research to place the matter on an experimentally demonstrative basis.

As this recomposition of sodium should take place at the mouths of all streams capable of carrying soils or soil colloids to the sea, and as it is persistent and closely correlated with the solvent action which gives rise to the true solutions, it should have large competency. There is a fair presumption that its competency is great enough to place sodium unqualifiedly among the active cyclic solid-liquid elements and to render its ratio to chlorine consistent rather than incongruous, when the prolonged history of the ocean is taken into account.[1]

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[1] A fuller discussion, with quotations and references, may be found in A symposium on the age of the earth: I. From the geological viewpoint, Trans. Amer. Phil. Soc. (1922).

HISTORY OF SCIENCE.

Sarton, George, Cambridge, Massachusetts. Associate in the History of Science. (For previous reports see Year Books Nos. 18–20.)

The general purpose of my work was set forth in my first report (Year Book No. 18, pp. 347 to 349). The present (fourth) report covers the period from September 1, 1921, to August 31, 1922.

1. *Introduction to the History and Philosophy of Science.*—This work is progressing well, though slowly. I have now reached the thirteenth century. A large quantity of notes relative to the development of science and civilization from the ninth century B. C. to the thirteenth century after Christ are completed, subject to addition and correction. To write the chapters dealing with these centuries will now be a relatively easy task. It will suffice to edit these notes, to place them in the proper order, and to compose for each century a special introduction, with synoptic and chronologic tables.[1]

2. *The publication of Isis.*—As pointed out in last year's report (Year Book No. 20, pp. 426 to 427), the publication of *Isis* is less a separate undertaking than a by-product of my main work. The writing of my Introduction obliges me to be familiar with all the latest research on the subject and to remain in touch with scholars who devote their lives to such investigations. Instead of keeping to myself the vast amount of information which I thus collect, I publish it regularly in *Isis*. The Introduction and *Isis* will eventually complete one another.

During the past annual period I have edited two numbers of *Isis*, Nos. 10 and 11 (t. IV, pp. 1–453). They contain 9 papers, 8 shorter communications, 82 reviews, and 1,163 bibliographic notes covering 152 pages (on the average, 7½ notes to a page). Some of these notes have been contributed by J. L. E. Dreyer (Oxford), L. Guinet (Brussels), L. C. Karpinski (Ann Arbor), and P. Masson-Oursel (Paris). It may be reasonably assumed that the longer reviews and the shorter notes taken together constitute a fair survey of the main investigations devoted to the history and philosophy of science and the history of civilization, recently published (i. e., down to October 1921). It should be noted, however, that this bibliography is selective, critical, and synthetic,[2] a method which is the more necessary in the present case, the number of futile and worthless papers and books being very great. My aim is, on the one hand, to discourage as much as possible the writing of such papers and books, and, on the other hand, to focus the readers' attention upon the more valuable contributions, the fruits of honest and intelligent research.

3. *The New Humanism.*—My efforts to promote the study of the history of science and to explain the ideals of the new humanism (that is, the reconciliation of the scientific with the humanistic spirit) are not divergent, but convergent; they are but two aspects of the same activity. That is natural enough, for the history of science is the backbone of the new humanism. It stands in the same relation to the latter as the history of Greek and Latin literatures stood to the humanism of the Renaissance.

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[1] For further information, see *Isis*, vol. IV, 23–31, 1922.

[2] For an explanation of this, see *Isis*, vol. III, 159–170, 1920.

This propaganda, it should be remarked, is essentially distinct from that aiming at the popularization of science. It does not appeal to the general public, but rather to mature scholars and scientists whom it tries to bring closer together. It does not attempt to make science more popular (which is usually done by laying stress on the applications), but rather to unify and deepen and thus to simplify it, to insist on the more abstract and the higher parts, to improve one's understanding of it by the knowledge of its origin and evolution. It does not try so much to get more people interested in science as to raise the scientist's own interest and broaden his sympathy.

I was given the opportunity to explain some of my views on the subject in a few lectures delivered before the Connecticut College for Women, Amherst College, the Marine Biological Laboratory of Woods Hole, and Harvard University.

Aside from the preparation of my Introduction and the editing of *Isis*, I have written the following papers: (1) Evariste Galois, *Scientific Monthly*, vol. 13, 363–375, October 1921. (2) Introduction to the history ard philosophy of science (preliminary note), *Isis*, vol. IV, 23–31, 1922. (3) The principle of symmetry and its applications to science and to art, *Isis*, vol. IV, 32–38, 1922. (4) The teaching of the history of science, *Isis*, vol. IV, 225–249, 1922. The last paper contains an elaborate discussion of the conditions of such teaching. Incredible as it may seem, there is at present but one single chair devoted to the history of science, that of the Collège de France in Paris, and ts incumbent, the mathematician Pierre Boutroux, died recently.

LITERATURE.

Bergen, Henry, Brooklyn, New York. *Research Associate in Early English Literature.* (For previous reports see Year Books Nos. 11–20.)

During the year 1922 the presswork on the first three parts of Lydgate's *Fall of Princes* has been finished and the volumes are nearly ready for issue. The first part (pp. I to LXV and 1 to 328) contains a brief general introduction and abstract of the contents of the poem, a study of the metre, the Latin and French prefaces and dedicatory epistles of Boccaccio and Laurence de Premierfait, and Books I and II of the text. The second part carries the text down from Book III to Book V (pp. 329 to 673), and the third part (pp. 675 to 1044), besides completing the 36,365 lines of text (Books VI to IX), contains as an appendix Lydgate's *Daunce of Machabree*, a poem of 672 lines, reprinted from Tottel's edition, London, 1554.

Work is progressing on the fourth and final volume of the *Fall of Princes*, which will contain a bibliographical introduction describing the printed editions and manuscript copies of the work, explanatory notes, a glossary, and an index. In the glossary it is proposed to treat all the words which have not already been included in the glossary of the *Troy Book*. After the completion of Part IV of the *Fall of Princes*, which is expected to be ready for the press early in 1924, Dr. Bergen will resume his work on the final volume of his edition of the *Troy Book*, containing the bibliographical introduction, notes, glossary, and index, on which he has been engaged for some years, and all of which is now in an advanced state.

Tatlock, John S. P., Leland Stanford Junior University. *Preparation of a Concordance to Chaucer.* (For previous reports see Year Books Nos. 16–18, 20.)

In the fall of 1921 Dr. Tatlock went to Scotland to consult the manuscript collations left by the late George Stevenson. From these he extracted a considerable number of valuable variants for the concordance, derived from practically all the extant manuscripts of the Canterbury Tales. He had previously gained the generous assistance of Professor R. K. Root for securing variants from all the extant manuscripts of the Troilus. Thus for three-quarters of Chaucer's poetry all important variants have been secured, it is hoped. Variants have also been obtained from all extant editions, including, by Professor F. N. Robinson's kind coöperation, his edition, which is not yet published. The purpose has been to make sure, so far as possible, that all readings likely at any time to be adopted by an editor shall be recorded in the concordance. Since his return from Scotland, Dr. Tatlock has been adjusting the arrangement of the quarter-million slips; that is, the numerous spellings for each word have been put together, and the pairs of words, sometimes separate, sometimes hyphened, and sometimes united, have been adjusted. This extensive task is almost finished.

MATHEMATICS.

Morley, Frank, Johns Hopkins University, Baltimore, Maryland. *Application of cremona groups to the solution of algebraic equations.* (For previous reports see Year Books Nos. 9–17, 19.)

Professor Coble has continued his researches along the lines mentioned in the last report. Two abstracts have appeared in the *Proceedings of the National Academy of Science* for August and December 1921. Three or four further abstracts will be submitted soon. A memoir on associated sets of points, related to the above work as well as to earlier papers, is in preparation for the *Transactions of the American Mathematical Society.* A general introduction to the subject which has grown up under the grant is given in Professor Coble's symposium lecture at the April meeting in Chicago, and will appear this fall in the *Bulletin of the American Mathematical Society.*

The two following problems still elude solution: Schottky has obtained formulæ for the ten nodes of a Cayley symmetroid in terms of modular functions of genus 4. Given, then, the symmetroid, to find a curve of genus 4 which defines these functions.

The rational sextic defines a group of genus 5, the symmetroid a group of genus 4, yet either figure determines the other. What is the connection thus indicated between the functions of genus 4 and of genus 5? The methods employed, though of necessity indirect, yield results which appear to bear on these problems.

MATHEMATICAL PHYSICS.

Moulton, F. R., University of Chicago, Chicago, Illinois. *Research Associate in Applied Mathematics.* (For previous reports see Year Books 5, 6, 8–19.)

The current year has been spent in completing the study of the question of stability of artillery projectiles, and in putting all the investigations on exterior ballistics in form for publication. The entire work is nearly ready for publication, and it will be sufficient to give a brief outline of the results obtained respecting stability.

The dynamical elements upon which the oscillations of a projectile depend are: A_1, the moment of inertia with respect to a transverse axis through the center of gravity of the projectile; A_3, the moment of inertia with respect to the axis of the projectile; ω, the angular rate of spin of the projectile; and M_1, M_2, M_3, the moments of the exterior forces.

Let the oscillations of the projectile be described by the curve traced out on a unit sphere by a line coincident with the axis of the projectile. Let P be the point on the sphere toward which the projectile moves. Then the axis of the projectile describes curves which, neglecting the curvature of the trajectory and the damping effects of the resisting forces, are contained between two circles C_1 and C_2 about P as a center. If the curves are both near P, the oscillations of the projectile are small. Since the projectile leaves the gun almost exactly nose on, one of the circles must be near P. The other may be far removed. If it is, the projectile undergoes large oscillations, or even tumbles and the motion is unsatisfactory.

Let θ represent the angle between the axis of the projectile and the direction of its motion. Let the moment of the exterior forces about a transverse axis of the projectile through its center of gravity be $A_1M \sin\theta$. Then the quantity

$$\lambda^2 = \frac{M}{\omega^2}\left(\frac{A_1}{A_3}\right)^2$$

plays an important role in all considerations of stability.

Whatever the value of λ^2, the projectile will have large oscillations if it is not started so as to have initially small transverse rotational velocity. A more important fact is that if $4\lambda^2$ much exceeds unity the oscillations will be large, however small the initial transverse velocity may be. Hence the projectile and gun must be so designed that λ^2 shall be sufficiently small.

The quantities A_1 and A_3 depend upon the shape and distribution of the mass in the projectile, ω depends upon the rifling of the gun and the speed of the projectile, and M depends upon the density of the air, the speed of the projectile, and unknown properties of its shape. The theory which has been developed leads to a method of determining M in case of any particular type of projectile by firing through card-board screens. The other quantities upon which λ^2 depends are all known.

It follows from the form of λ^2 that projectiles in respect to the question of their stability have the following properties:

(1) For velocities of the projectile below the velocity of sound, M varies nearly as v^2. Since ω varies as v^2, the stability of a projectile is independent of its velocity so long as the velocity remains below that of sound.

(2) Since the resistance of the air to a projectile varies as a higher power of the velocity than the second for velocities near that of sound, a projectile may be stable for velocities below that of sound and unstable for velocities above that of sound.

(3) The greater the density of the air the less the stability of the projectile. Hence, if a projectile is stable near the gun it will be stable throughout its flight. Only if it is near instability and fired at a high angle can there be an exception.
(4) The longer the projectile of a given diameter the less its stability.
(5) For a given velocity of translation, the higher the rate of spin of a projectile the greater its stability.
(6) Two similar projectiles of different dimensions fired with the same velocity from guns rifled one turn in a given number of calibers have the same stability.
(7) If the length of a projectile near instability is increased by the factor C the pitch of rifling must be increased by the factor $\sqrt{C}$ to preserve the stability.

The motion of the axis of the projectile can be analyzed into two periodic motions, one between the two circles C_1 and C_2, and the other around the point P. If C_1 is the smaller of the two circles, the curve described by the axis is always tangent to C_2 and is described in the direction of spin of the projectile. It may be tangent to C_1 in either direction, depending upon initial conditions, and it may have a cusp on C_1. For given circles C_1 and C_2 the axis may make many oscillations between C_1 and C_2 without completing a circuit about P, or it may make a circuit about P with each oscillation, according to the initial conditions. In firing from well-constructed and well-mounted guns, the circle C_1 is very small, and hence the two cases are physically not much different from each other.

The periods of oscillation of the axis of a projectile between the circles C_1 and C_2 and about the point P have the following properties:

(1) The period of oscillation between two given circles, C_1 and C_2, varies nearly inversely as the velocity of the projectile.
(2) The period of oscillation between two given circles, C_1 and C_2, is greater the greater the density of the air.
(3) The period of oscillation between two given circles, C_1 and C_2, is greater the longer the projectile.
(4) The period of oscillation between two given circles, C_1 and C_2, is shorter the more rapid the spin of the projectile.
(5) If the circle C_1 is small, the period of oscillation between C_1 and C_2 is shorter the larger C_2.
(6) The two periods of oscillation around P are both shorter the smaller C_2.
(7) The two periods of oscillation around P are both longer the longer the projectile.
(8) The two periods of oscillation around P are both shorter the higher the rate of spin of the projectile.

METEOROLOGY.

Bjerknes, V., Bergen, Norway. *Preparation of a work on the application of the methods of hydrodynamics and thermodynamics in practical meteorology and hydrography.* (For previous reports see Year Books Nos. 5–20.)

The importance of the atmospheric surfaces of discontinuity and their connection with the cyclones have been emphasized in the reports for the last years. The continued investigations have led to the following general view of the meteorological phenomena of the temperate zone and their rôle in the general atmospheric circulation.[1]

The cyclones of the temperate zone originate and propagate as waves in atmospheric surfaces of discontinuity. These surfaces, or at least their most conspicuous sections, extend from southwest to northeast. The cyclones generate in the region of the southwest extremity and die off in the region of the northeast extremity, being, during their propagation, gradually transformed from propagating waves to stationary vortices. In this way a somewhat varying number of cyclones may coexist in the same surface of discontinuity. The most generally occurring numbers seem to be two, three, or four.

The entire system of the discontinuity with its propagating cyclones has itself a motion from west to east. The cyclones are always moving through this propagating system from its rear, where they originate, to its front, where they die. Therefore the velocity of propagation of the individual cyclones is considerably much greater than that of the discontinuity with its "cyclone family."

Such a family of cyclones is generally succeeded by a northerly current with anticyclonic weather conditions. Then follows a new discontinuity with its family of cyclones, again succeeded by the northerly current and the anticyclone, and so on. This repeats itself with great regularity. The interval between the arrival of one cyclone family and the next is 5½ days on the average. *This gives the explanation of a remarkable climatological period of precisely this length,* which has been found through statistics made upon the different meteorological elements in a variety of different places of the northern hemisphere.

When we combine this length of period with the geographical extent of the cyclone families or with their velocities of propagation as measured on the charts, we arrive at the following view of the general atmospheric circulation of the northern hemisphere:

In general there exist four currents conveying polar air from the polar regions to the trades. These four currents originate at right angles with each other, but turning to the right they get a spiral form with a general direction from northeast to southwest. Between and above these polar currents we have a general poleward motion of tropical air, directed from southwest to northeast. The system of these four polar currents goes round the earth from west to east, performing an entire revolution in 22 days. At the left flank of these revolving currents we have the moving discontinuities in which the cyclones propagate. At the right flank we have the anticyclone, which follows after one cyclone family and precedes the next. The successive families must then follow each other, with the mentioned interval of 5½ days.

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[1] Cf. J. Bjerknes and H. Solberg, Life cycle of cyclones and the polar-front theory of atmospheric circulation, Geofysiske Publikationer, vol. III, No. 1, Kristiania (1922).

The regularity of the system is broken by the irregular distribution of oceans and continents, by the topography of the latter, and by the seasonal changes of thermal conditions. This may cause one or more of the polar currents to be for some time cut off before they reach the trades; thereby two or more of the advancing discontinuities may for some time be joined to a single "*polar front*," while in general we have to count with *four distinct polar fronts*, or advancing left flanks of the polar currents. It may happen also that one of the moving polar currents is checked for some time in its eastward propagation at the western coast of a continent, producing thus a stationary current feeding the trades, while the rest of the system continues its regular propagation eastward.

Irregularities of this kind can not, however, hide the grand regularity underlying the system; and this regularity is of an extreme importance to weather forecasting. As a matter of fact, the Norwegian Weather Service has begun to supplement the ordinary forecasts for the next day with long-range forecasts, giving the general weather conditions for the next period of five days. These long-range forecasts are based upon the knowledge, which the weather telegrams obtained from the Atlantic, and in the latest time also from America, give of the situation and the probable movement of the next cyclone family. *As the movements of the cyclone families are far more regular than those of the individual cyclones, these forecasts succeed rather better than the short-range forecasts for the next day*, although the telegrams from the Atlantic and America are not yet at all adapted to the needs of this service of long-range forecasts.

Similar long-range forecasts ought to succeed at least equally well in the eastern parts of North America, as there is good opportunity to observe in due time the invasion of the cyclone families from the Pacific to the Western States. And with sufficient marine messages from the Pacific and from Japan, they should succeed even for the entire North American continent.

NUTRITION.

Osborne, T. B., and L. B. Mendel, New Haven, Connecticut. *Continuation and extension of work on vegetable proteins.* (For previous reports see Year Books Nos. 3–20.)

Students of the vitamine problem seem at present to be in accord in the belief that the now-recognized food accessories are not synthesized *de novo* by the higher animals, but are derived from their food-supply. Furthermore, the comparatively rapid onset of symptoms of disorder following the lack of vitamine B in the diet leads to the conclusion that normal animals do not possess any large available reserve of this food factor. It is of obvious importance, therefore, to secure a quantitative estimate of the actual amounts of the different vitamines requisite for the proper physiologic function of the various animal organisms at all stages of their existence and under the different conditions represented by unlike age, sex, activity, diet, planes of metabolism, or other possible modifying circumstances. Published statements have awakened a widespread belief that vitamine B is essential primarily for growth. The evidence, however, is not very cogent, particularly in view of the admitted fact that the common experimental animals of all ages inevitably decline when vitamine B is omitted from their diet.

In our report for last year we stated that an extensive series of feeding trials was in progress in which the only variable, aside from the variations in the voluntary daily food intake, has been the amount of vitamine B fed daily, apart from the rest of the ration, as tablets containing dried brewery yeast. These tests continued over a period of one year for each animal, the beginning of such a dietary régime being made at different ages (and consequently different sizes) with animals previously maintained on the mixed diet customarily furnished after weaning to our stock colony. In this way the doses of this yeast required at different ages until adult size was reached could be ascertained; also whether a more or less prolonged preliminary period of less "artificial" feeding on food mixtures which have been demonstrated to be adequate in every respect for the nutritive well-being of the rat would alter the subsequent vitamine requirement. Thus, the feeding trials in successive groups on the same yeast dosage were begun when the animals had reached approximately 40, 70, 150, and 240 grams respectively of body-weight. The results of these experiments are nearly ready for publication.

Obviously, when the daily intake of yeast remains unchanged while the animal is growing, the dosage of vitamine estimated on the basis of body-weight, stature, or surface area becomes progressively altered. An estimate of the actual dosage in our numerous experiments under strictly comparable conditions in terms of 100 grams body-weight is admittedly open to theoretical objections, just as are the various units which have been proposed for the record of basal metabolism.

Broadly speaking, it appears as if the vitamine B requirement in the case of the rat under conditions of growth or maintenance upon a food of constant qualitative and quantitative make-up bears a fairly definite quantitative relationship to the mass of active tissue. Under the conditions of our experiment the daily requisite per hundred grams of rat approximates what is contained in 50 to 60 milligrams of our dry yeast. This conclusion is reached by observing the weight of the animals for which maintenance is either barely possible or no longer satisfactory in the numerous individual experiments on different fixed daily doses of yeast.

Our numerous data indicate, however, that per unit of body-weight the larger animals may have a somewhat smaller requirement than the small growing ones. This, perhaps, is explained in part by the relatively larger content of adipose tissue in the adult individuals. In any event, the major thesis is clearly substantiated.

The problem has further been considered from a somewhat different angle by observing the effect of measured daily doses of vitamine B, administered in the form of yeast, upon animals which had previously grown on our customary mixed diet instead of the specific unvarying ration discussed in the previous experiments, as it might be assumed that if vitamine B storage in the body depends on the character of the diet, animals raised upon different sorts of food might subsequently respond differently to the same daily vitamine dosage. No appreciable difference, however, was observed.

Our experience with dry yeast as a source of vitamine B has been corroborated by similar experiments with the concentrate from yeast extract first prepared by us several years ago. Thus, with a daily dose of 40 milligrams of this product, growth usually stopped when the rats reached a size not far from 200 grams in body-weight; but weight was subsequently gained when more of the concentrate was fed, and growth then continued until a new maintenance level was reached, whereupon larger doses of the yeast-concentrate again promoted growth. Likewise, when naturally occurring foods such as green vegetables were used as the sole source of vitamine B, larger quantities were required for normal growth as the animals increased in size.

The possibility of supplying the vitamines in small daily doses apart from the energy-bearing portion of the ration has made it possible to consider some of the problems of metabolism from new viewpoints. It has already become apparent that some of the current traditions regarding the requisite relative proportions of protein and the non-nitrogenous nutrients in the diet must be, in part at least, abandoned in the light of our findings.

The unexpected growth of animals to considerable size on diets almost free from carbohydrate or fat, or from both, encouraged us to undertake further investigations on the effects of such unusual food mixtures. In our more recent experiments some animals have grown at a normal rate to more than 260 grams on diets of which more than 90 per cent consisted of protein. Evidently, if any considerable quantity of carbohydrate is requisite for normal metabolism it must have been derived from the amino-acids of the ingested proteins. It has been reported that different species of animals on high-protein diets suffer from albuminuria, and the implication is that kidney defects arise. It is hardly conceivable in the case of our rats fed on high-protein diets that they should have continued to grow to almost normal adult size at a satisfactory rate if the renal organs had been seriously damaged. The histology of animals which have grown up on such unique diets remains to be investigated; likewise the possible changes in tissue composition, fat production, and other chemical factors incident to gain in weight.

Thus far none of the animals on the high-protein diets has ultimately reached the average adult size attained by rats fed on our standard food mixture containing only 18 per cent of protein. Whether this is due to the failure of the adult animal to construct fat, or to an actual interference with tissue growth as the result of the unique diets used, has not been determined. It is worthy of note, however, that when the larger animals which have been brought to a body-weight of 250 grams, or thereabouts, on these high-protein diets are given food containing carbohydrate and fat and only 18 per cent of protein, as a rule they make considerable additional gains.

When the protein in the diet does not exceed 80 per cent of the food mixture, and is supplemented by small amounts of starch or fat in addition to the inorganic salts and vitamine-bearing components, growth as a rule has extended to larger size than was the case in the first series of animals referred to. Wherein the superiority of this lower concentration of protein lies, if it proves to be a real one, remains to be ascertained. In any event, it is surprising to find how readily the rat can use such extremely large quantities of protein for growth. It is also interesting to note that the amount of these high protein foods eaten by the rats is no greater than of those of equal calorific value containing a liberal proportion of carbohydrate and very much less protein, thus showing that protein meets the energy requirements of the rat almost, if not quite, as well as does carbohydrate.

Another extreme type of diet recently studied involves the feeding of a ration containing at least 75 per cent of fat and devoid of more than insignificant amounts of preformed carbohydrate. On such mixtures some animals have grown to 280 grams, although the rate has usually been somewhat slower than the normal. This represents about the upper limit of possible fat-content in the diet of growing animals; for the food intake seems to be determined, when the food mixture is qualitatively satisfactory, by their calorific needs. On such diets, relatively very rich in energy, the total weight of food eaten is so small that the absolute intake of protein is too low to permit a normal rate of growth. Thus, with as much as 80 per cent of fat in the diet and a protein-content not exceeding 15 per cent, animals do not grow, but are maintained for long periods at constant weight until the fat-content of the diet is materially reduced. Apparently the failure to grow in such cases is not due to any toxic effects of the large intake of fat, but rather to the enforced reduction of the other essential factors of the diet. Our experiments with diets having such unusual relative proportions of the nutrients have a bearing upon the current discussions of the balance of ketogenic and antiketogenic products in intermediary metabolism.

Several years ago we showed that after rats have been maintained without growth for very long periods—in some cases beyond the age of 500 days—they have not lost the capacity to grow, even though they have long passed the time at which adult life is normally reached. It was concluded that the capacity to grow is not lost until it has been exercised, a conclusion somewhat at variance with some of the then current theories. At that time, however, our experiments were stopped before the realimented animals had reached full adult size.

Since it is believed that malnourished children do not develop into such large men and women as do the well nourished, it has been suggested that had these experiments been continued it would have been found that the stunted animals would not have grown to be as large as the average normal rat. In this way comparatively small types of adults might arise. To answer this question we have undertaken new experiments in which the animals have been dwarfed at a comparatively early age for considerable periods through chemically inadequate diets and are now being permitted to grow through a change to a liberal mixed diet. We shall soon be in a position to determine to what extent, if at all, the stunting in earlier years may have altered the ultimate capacity to attain adult stature.

In preparation for the foregoing tests, we have repeated some of our earlier investigations in suppression of growth through the use of the protein gliadin which is relatively deficient in the indispensable amino-acid lysine. So far as it concerns the inability to grow despite an otherwise adequate diet, the outcome has corroborated our earliest observations. Professor H. H. Donaldson, of the Wistar Institute, has made measurements of a number of animals which have been kept without exceeding a weight of approximately 100 grams over periods of 100 and 200 days respectively. His findings will afford comparisons of the development of the different organs and skeleton under conditions of prolonged suppression of growth. It is worthy of note that some of these stunted animals on the gliadin diets were at first intentionally maintained for some time on food devoid of vitamine A, whereupon they developed the characteristic ophthalmia and were in turn completely cured, although without growth, by the administration of cod-liver oil; despite these periods of undoubted ill health, the ultimate capacity to grow has been maintained. Even during maintenance without growth at relatively early ages, the pathological manifestations of deficiency of vitamine A exhibit themselves. This is contrary to our former belief that the pathological effects of lack of vitamine A failed to manifest themselves so long as no growth took place.

In view of the fact that gliadin yields a measurable, although extremely small, quantity of lysine, it might be supposed that, provided sufficient of the protein could be utilized, growth could occur even on gliadin. In experiments in which this protein constituted 80 per cent of the entire otherwise appropriate food we have found that this is the case. Rats fed on this mixture from the age of 30 to 40 days doubled their weight within 45 days.

The question of the vitamine-content of milk has, very properly, attained considerable prominence, not only in its scientific aspects in relation to nutrition, but also from the standpoint of public health. Experiments undertaken by us at various times have indicated the necessity of feeding as much as 16 c. c. of fresh cow's milk per day as the sole source of vitamine B to secure growth at a normal rate. These results have been substantiated by several investigators; and although there appears to be a variation in some cases in the vitamine B content of milk, depending on the character of the diet of the cows, the results have, with the exception of Hopkins's experiments, been in harmony with our own in showing that even under the most favorable circumstances it requires additions of more than 10 c. c. of milk per day to effect a food intake adequate for the growth of rats at a normal rate. The successful results obtained by Hopkins with as little as 2 c. c. of milk per day, fed in the same way, have stimulated us to renewed tests in which the feedings were begun, as in most of Hopkins's experiments, when the rats were still quite young, often weighing not more than 40 grams. These new experiments have corroborated our earlier ones, which showed that milk is not particularly rich in vitamine B in comparison with many other natural foodstuffs. Neither seasonal variations, differences in the rations fed to the lactating cows, nor manipulations of the milk prior to marketing appeared to offer a satisfactory explanation of the differences between our results and those recorded by Hopkins.

Experiments described in the literature of the vitamines have suggested that egg-yolk might be an unusually advantageous source for preparing extracts high in their concentration of vitamine B. Preliminary tests which we have made with fat-free concentrates have failed, however, to yield preparations of relatively high potency from this source. It thus appears that the egg yolk, like the milk, is not unusually rich in vitamine B.

In an earlier paper dealing with citrus fruits, we stated that preliminary tests indicated that dried orange juice contains some vitamine A. This conclusion was based on the fact that when the equivalent of 10 c. c. of the juice was furnished daily to rats on a diet practically devoid of vitamine A, the symptoms which should characteristically ensue did not develop within the period of 190 days during which our observations continued.

A reinvestigation of the subject has substantiated our earlier conclusion. Owing to the comparative richness of orange juice in carbohydrates, so that 10 c. c. represent a not inconsiderable intake of nonprotein calories, the proportion of protein and essential salts in the ration was made large enough to promote growth at the normal rate. A number of rats maintained on this diet, consisting of casein, starch, lard, and salt mixture, together with 0.2 gram of dried brewery yeast as a source of vitamine B, developed the characteristic ophthalmia associated with a lack of vitamine A and were completely cured within a few days after the daily administration of either 10 c. c. of fresh orange juice, or the same amount of juice admixed with starch and desiccated in a current of hot air. To cure the ophthalmia, 5 c. c. of juice sufficed, but a larger quantity appeared to be necessary to secure restoration of growth. Inasmuch as Cooper has reported the presence of vitamine A in orange peel, special precaution was taken in our work to avoid contamination of the juice with the latter.

The data now available from animal-feeding experiments indicate the presence of vitamines A, B, and C in the orange and the possibility of conserving them, in part at least, by suitable processes of desiccation. Our experiments indicate that, volume for volume, orange juice is as rich as is milk in vitamine B, but somewhat less rich in vitamine A. According to the data furnished by Givens and McClugage, orange juice is much richer than milk in vitamine C.

Experiments with rats have shown that celery, dandelion, and parsley contain noteworthy amounts of vitamine B. The edible parts of asparagus, celery, and lettuce contain much more vitamine B than do apples, pears, or the juice of grapes. The foregoing evidence serves anew to emphasize the importance of these vegetables in the diet of man.

It is interesting to note that decoctions of tea leaves, stronger than those ordinarily drunk by man, failed to supply sufficient vitamine B for rats on an otherwise adequate diet, even when 10 c. c. of the decoction, which formed the sole source of water intake, was consumed per day.

It has been surprising to us, as well as to other investigators in this field, to find that animals which have grown splendidly on rations consisting of purified proteins, fat, carbohydrate, and salt mixtures, together with fats bearing vitamine A and yeast as a source of vitamine B, almost invariably fail to breed, although their general appearance indicates that they have developed normally. Examinations made in collaboration with workers in Professor Harrison's laboratory at Yale University have shown, however, that the gonads of both the male and female animals as well as the œstrous cycles of the latter are extremely abnormal. An extensive study of these abnormalities is planned. It is interesting to note that small additions of egg-yolk, and probably other naturally occurring foods, to the diets suffice to avert sterility. An opportunity to investigate the relation of the diet to the development and functions of the gonads is thus presented. The preliminary observations which we have made may help to explain some of the anomalies of reproduction frequently encountered in the case of domestic animals.

Doctors A. M. Yudkin and R. A. Lambert, of the Yale School of Medicine, have studied the pathology of the eye in relation to the ophthalmia which we first described several years ago in the case of rats fed on diets deficient in vitamine A. These investigations, made on animals which we prepared for them, showed that the changes in the eye do not begin in the cornea, but have their origin in the lids. In this respect they resemble the severer types of acute and chronic conjunctivitis which are frequently complicated by corneal injury, with infection, and ulceration of this structure. They also found that the lacrimal glands may be the seat of a marked pathological change, either degenerative or inflammatory in nature. Such changes are much more marked in xerophthalmic than in normal rats. Variation in the size, form, and staining properties of the cells are frequently seen and are probably referable to functional disturbances related to the ophthalmia. This may account for the drying of the cornea in the later stage of xerophthalmia.

We have also attempted to ascertain whether a relative deficiency of vitamine B will hasten the appearance of ophthalmia on a diet also devoid of vitamine A. The onset of visible signs of this disease is, as a rule, somewhat more rapid under these conditions, and the increase in the supply of either vitamine will improve the defect for which its lack is *specifically* responsible without benefiting the animal noticeably in respect to its other deficiency. Thus, an intake of an adequate supply of vitamine B will not relieve the eye symptoms, nor will the mere addition to the diet of vitamine A, in the form of cod-liver oil, promote growth, although careful ophthalmological examination may show that the ophthalmia is completely cured.

The elaborate chemical fractionation of the alfalfa plant as a type of living leaf cell has incidentally furnished a variety of products which may be of interest in the study of the distribution of vitamines in plants. Preliminary investigations, which we have already undertaken, promise to give some interesting information and may, perhaps, pave the way for a better understanding of the chemical character and behavior of some of the vitamines.

A study of the fractions obtained from the green alfalfa plant has been made, attention being chiefly devoted to the water-soluble nonprotein substances. The purpose of this investigation has been to find methods whereby the water-soluble constituents of the juice could be separated into groups suitable for further study, rather than to the isolation of individual chemical compounds. As a preliminary to this examination, careful analyses have been made of the ashes of the "colloid precipitate," the precipitate produced by adding 53 per cent of alcohol to the filtrate from the "colloid precipitate," and of the solids of the filtrate from the latter precipitate. We have thus established the relative proportions of each of the inorganic ions in these three fractions. No evidence was obtained that any considerable part of these elements was in organic combination. It was thus found that addition of 53 per cent of alcohol to the clear alfalfa press juice removed considerably more than half of the inorganic constituents and left only a small part of the calcium, phosphoric acid, or sulphuric acid in the solution.

The filtrate from the 53 per cent alcohol precipitate, which contains about half of the nitrogen of the alfalfa juice, presents an opportunity for obtaining a better knowledge of its nonprotein nitrogenous constituents than we now have. Although these undergo continuous changes during the growth of the plant and can therefore not be dealt with from a quantitative, or even a qualitative, standpoint, with any high degree of accuracy, nevertheless we have obtained analytical results with different lots of plants which agree more closely than we at first expected and give a general picture of the types of compounds present in the juice which should ultimately contribute to a better knowledge of these substances than we now have.

Thus, by applying Hausmann's method for determining "ammonia," "humin," and "basic" nitrogen, and Van Slyke's method for amino nitrogen, we obtained the following results with three different lots of alfalfa plants, expressed in percentages of the total nitrogen:

	Before hydrolysis.			After hydrolysis.		
	No. 49.	No. 54.	No. 57.	No. 49.	No. 54.	No. 57.
Ammonia nitrogen	5.7	3.0	4.5	17.0	16.9	14.2
Basic nitrogen	44.4	38.7	51.3	20.4	25.9	19.0
Humin nitrogen	1.3	....	1.4	11.2	6.9	16.4
Free amino nitrogen	29.2	25.2	23.8	41.7	46.3	38.3

In view of the fact that these methods were primarily designed for application to the products of protein hydrolysis, as well as to the fact that these three lots of alfalfa were not of precisely the same age, the agreement between these analyses is sufficiently close to justify useful conclusions.

Before hydrolysis, ammonia salts are present in relatively small proportion and substances containing nitrogen converted into ammonia by hydrolysis are present in no inconsiderable amount. Basic substances, precipitable by phosphotungstic acid, contain from 40 to 50 per cent of the water-soluble alfalfa nitrogen which by hydrolysis is reduced to about one-half as much, presumably largely through the loss of nitrogen which is converted into ammonia and "humin" nitrogen. Thus the sum of the basic "humin" and of the increase in ammonia nitrogen is respectively 43.1, 46.7, and 45.1 per cent of the total nitrogen, which figures do not differ very widely from the basic nitrogen found before hydrolysis. After hydrolysis the proportion of free-amino nitrogen is about 50 per cent greater than before, which may, or may not, mean that peptides are present in the juice.

Examination of the basic nitrogen by Kossel's method for separating arginine, histidine, and lysine showed that about 16 per cent was precipitated by silver nitrate and baryta, but no evidence of the presence of arginine or lysine was obtained. The color reaction with diazobenzene sulphonic acid, as well as the small precipitate produced by $HgSO_4$, indicated the presence of a little histidine, but as both of these reactions are given by other nitrogenous substances, they can not be accepted as proof that histidine is actually present.

The filtrate from the silver nitrate-baryta precipitate yielded no lysine picrate, but a relatively considerable amount of a much more soluble picrate, which has not yet been obtained in sufficient quantity for indentification.

The freshly expressed juice of the alfalfa plant is strongly colored and its color for the most part remains in solution after adding 53 per cent of alcohol. This solution, when concentrated, appears black by reflected light, but clear ruby-red by transmitted light. A part of this color is removed by shaking with iso-amyl alcohol, and this is presumably present in the free state. When the acidified aqueous layer is again shaken with iso-amyl alcohol a somewhat larger quantity is removed, probably set free from salt-like combination.

When the aqueous layer is gently hydrolyzed by boiling with very dilute hydrochloric acid an insoluble product separates, in highly hydrated clumps, which dissolves in absolute alcohol with a characteristic deep brown color.

By shaking the filtrate from this latter product with normal butyl alcohol, or with iso-amyl alcohol, a further considerable amount of substance is extracted having the color characteristic of that previously extracted by amyl alcohol. The color and properties of this coloring matter resemble those characteristic of flavones, but as yet we have not obtained convincing chemical evidence that these alfalfa coloring substances actually belong to this group. Such data as we have secured show that these flavone-like substances are present in relatively large amount, chiefly combined with protein in the insoluble fractions of the alfalfa and with other substances, as yet unidentified in the soluble fractions. Further investigations of these interesting products are in progress, which, if successful, may contribute facts of importance to a knowledge of the chemistry of the cell. This latter surmise is supported by the fact that the colorless cells of the yeast plant, after hydrolysis with dilute acid, yield colored solutions when shaken with normal butyl alcohol which can not be distinguished by the eye from those similarly obtained from the alfalfa press juice. This observation indicates that these colored substances are not necessarily concerned in the photosynthetic processes of the leaf.

Besides these colored substances, amyl, or butyl, alcohol extracts from the products of hydrolysis of the solids of the alfalfa juice a large amount of hydrochlorides of basic substances, possibly largely amino-acids, which render the isolation of colored substances in a state of purity a matter of great difficulty. However, a beginning has been made in dealing with the complex mixture of compounds contained in the juice of this leaf, and it now appears to be only a matter of time and patience to obtain an insight into the chemistry of the plant cells which promises to yield much that is new and interesting.

The detailed results already secured have been published in the *Journal of Biological Chemistry.*

Preliminary studies of the rate of hydrolysis of gliadin, the alcohol-soluble protein of wheat, which have been mentioned previously in the Year Book, showed that it was possible to obtain results of value in this hitherto little investigated field. At our suggestion Dr. H. B. Vickery made this the subject of his dissertation presented to the Faculty of Yale University as candidate for the degree of Doctor of Philosophy.

This investigation presented the problem of the rate of hydrolysis of two types of binding of nitrogen in the protein molecule which proceed simultaneously, as well as the isolation of the products of partial hydrolysis at various definite stages of the decomposition of the protein molecule. Since obtaining his degree Dr. Vickery has joined our staff and is continuing this investigation. The details of the results already obtained have been published in the *Journal of Biological Chemistry* and need not be recounted here, as an intelligible account of them would require too much space. It may be stated that this work has opened a field of study that promises much of interest in respect to the chemical constitution of the protein molecule.

In coöperation with Dr. H. Gideon Wells, of the University of Chicago, a study of the anaphylaxis reactions of the proteins of cow's milk has been made with preparations produced in our laboratory. The results obtained by Dr. Wells show that milk contains at least four chemically distinct proteins, namely casein, lactalbumin, lactoglobulin, and an alcohol-soluble protein. Only one of these proteins, lactoglobulin, sensitized guinea-pigs to the serum of beef blood, which confirms the observation of Crowther and Raistrick that actoglobulin and serum globulin are chemically indistinguishable.

PALÆOGRAPHY.

Lowe, E. A., Oxford, England. *Associate in palæography.* (For previous reports see Year Books 9–16, 19–20.)

With a view to continuing the researches in uncial manuscripts, of which mention was made in my previous report, it was planned to visit the libraries of Germany and Austria, which have important representatives of uncial writing. After completing investigation of the manuscripts of Vienna and the manuscripts of St. Paul in Carinthia, which, thanks to the courtesy of the Abbot, were sent from the monastery to Vienna, further work was abandoned owing to my illness. However, considerable progress has been made.

Another unknown fragment of Virgil with the Greek translation was found in the Rainer collection of papyri in Vienna, which, with the similar fragment discovered in the Ambrosiana of Milan, forms the subject of a short article in the next number of the *Classical Review.* The fragments are insignificant in themselves, but they bear witness to the popularity of Virgil in Egyptian education of the fifth and sixth centuries. One of the chief problems connected with manuscripts is the discovery of criteria for detecting the precise region or center where a manuscript was written. An article on *The African Home of the Codex Palatinus of the Gospels* which has just appeared in the *Journal of Theological Studies,* is an attempt to throw some light on this side of palæography. In March a paper was read before the Oxford Philological Society on *Omission Signs in Latin Manuscripts.* As these signs serve at times as clues to the date and origin of a manuscript, their importance is clear. The paper will be printed in an early issue of the *Classical Quarterly.* Two works of palæographical interest were reviewed for the *English Historical Review.*

In the course of work upon uncial manuscripts, the type known as half-uncial was continually borne in mind, and sufficient data have been collected to make it possible to publish the first comprehensive list of half-uncial manuscripts. Under the writer's guidance, Mr. W. J. Anderson, of Christ Church, Oxford, has been making a catalogue of published facsimiles of Latin manuscripts. Although this catalogue is intended primarily to serve the immediate purposes of the new collection of palæographical negatives, made possible by the generosity of the trustees of the Carnegie Institution, it is so valuable and convenient an aid to scholars dealing with original sources that its publication seems highly advisable.

Progress has been made with the collection of palæographical negatives. Over 250 negatives have been acquired during the year. The practical question of housing these negatives and of making them accessible to scholars has been under consideration. The value of this collection is shown by the fact that the Bodleian Library of Oxford is ready to become its custodian for the Carnegie Institution. The Carnegie Institution could hardly do better than to intrust the collection to the Curators of the Bodleian, with the understanding that the negatives are the property of the Institution and may be removed to other quarters if that should seem desirable.

PHYSICS.

Barus, Carl, Brown University, Providence, Rhode Island. *Continuation of investigations in interferometry.* (For previous reports see Year Books Nos. 4, 5, 7–20.)

Dr. Carl Barus has submitted to the Institution a report on the development of the acoustic investigations with the pin-hole probe, begun in the preceding communication (Carnegie Inst., Wash. Pub. No. 310, 1921). The introduction shows that the pin-hole probe responds effectively to nodes in organ pipes and that it ignores the antinodes. In the case of the usual air-blown diapason pipes, the presence of the air-current naturally interferes with the acoustic experiment. If, however, the pin-hole is surrounded by a minute bag of porous material, a consistent registry of nodes again appears, but constructed on a base of increasing pressures, positive or negative.

With a device so sensitive to nodal regions in vibrating pipes, the construction of a pin-hole resonator suggests itself. The latter, if designed with but a single mouth and responding correlatively to a closed organ-pipe of the same pitch, is preferred in the interest of simplicity. However, unless the pin-hole is adapted to the resonator, no acoustic pressures whatever are evoked. It was eventually found that not only the size, but the slope of the walls of the pin-hole are critical; that a salient pin-hole generates acoustic pressure, a reëntrant pin-hole acoustic dilation, and there is neutral behavior between the two. With a properly designed pin-hole, pressures, whether positive or negative, will be about equal; it follows, therefore, that by coupling them with the corresponding shanks of the mercury U-tube, an advantage in sensitiveness is secured; but it does not seem feasible to push the sensitiveness of the pin-hole indefinitely farther, for it appears to be the nature of these occurrences to drop off exponentially.

Though the project of relaying pin holes would seem to be quite at hand, all experiments with this end in view remained persistently negative. With so many pin holes in series that displacement of the mercury in the U-tube was absolutely dead-beat, the acoustic response was no better than for a single pin-hole.

The work has a direct bearing on the behavior of sensitive flames. If an adjusted pin-hole burner becomes turbulent by slight increase of pressure within, a sound-wave passing the burner will supply this pressure acoustically. Experiments with branched tubes and one or two (salient and reversed) pin-holes present many points of interest, particularly on account of the eventual bearing of the data obtained on the sensitiveness of telephones.

Within its restricted field, the pin-hole resonator serves admirably for the acoustic survey of the interior of a room in which an organ-pipe is sounding. For a given position of the pipe, nodal regions alternate with antinodal regions, quite irregular in distribution, but none the less fixed in position. The author has cut through this acoustic topography in all directions from the position of the pipe, with the expectation of arriving at some general facts as to distribution; but it is difficult to state the results, otherwise than by the graphs in the text. These show a difference in the character of a survey between walls contrasted with one toward an open door; but (*a priori*) one would not be able to predict the occurrence of either type.

A very satisfactory experimental equipment tries out the effect (if any) of an electric current on rays of light. These pass in parallel with the current through the same long channel, both in case of an exhausted tube and of an electrolytic trough. Such an effect was hardly to be expected and none was found. In the sequel some useful improvements are added to the self-adjusting interferometer.

An endeavor is made to ascertain to what degree the constant of gravitation may be found in a self-contained apparatus under ordinary laboratory conditions, and it contains two groups of measurements. The first, made in a moderate vacuum of a few millimeters and with a relatively thick quartz fiber, gave a value trustworthy within 1 per cent. Thereafter a much thinner fiber was tested, giving excursions 5 to 10 times larger, the needle swinging in partial vacua. The mean elongations of the needle at night seem to be trustworthy; but the long period of the needle could not now be found with anything like adequate accuracy. So dependent is this period on the thermal environment that early morning and afternoon observations may vary from 600 to 800 seconds, the individual data themselves being quite accurate. A storm passing over the laboratory dropped the period from 750 to 626 sec., after which it rose again to 712 sec. Of course it would be possible to determine the modulus of the fiber by a separate small body; but this would be at variance with the plan of the experiments. The work will be resumed this summer under the highest attainable exhaustions, as the experiments show this to be indispensable.

Hayford, John F., Northwestern University, Evanston, Illinois. *Investigation of the laws of evaporation and stream-flow.* (For previous reports see Year Books Nos. 12–16, 19, 20.)

One year ago the evaluation of the effects of winds and of barometric pressures in disturbing the elevation of the water surface at Buffalo and Cleveland on Lake Erie, and at Milwaukee, Mackinaw, and Harbor Beach on Lake Michigan-Huron, had been completed. It was then decided that the next step should be the determination of laws of evaporation from the surface of the lakes and the incidental determination, so far as possible, of the laws controlling stream-flow into Lake Michigan-Huron and into Lake Superior.

These two lakes were chosen, on the basis of the extensive preliminary investigations already made, as being the ones for which the greater accuracy would be secured in the determination of evaporation and stream-flow from a given amount of work. On each of these lakes the elevation of the mean surface of the whole lake, and therefore the total water-content of the lake, may be determined for each day with a much higher degree of accuracy than is possible for Lake Erie or Lake Ontario. It now appears that the probable error of the computed change of elevation in one day of the mean water-surface of either Lake Michigan-Huron on Lake Superior is less than ±0.02 foot. That is, the change of elevation of the mean water-surface, from any day to the next, may be computed so accurately from the observed meteorological facts around the lake—humidities, temperatures, rain-fall—that the computed value will be within 0.02 foot of the truth in more than half of the cases.

The effects of barometric pressure in producing disturbances of the elevation of the water-surface at Marquette, the gage station on Lake Superior, have been evaluated in 1922 by the method which had already been applied at the five gage stations on Lakes Michigan-Huron and Erie. This was a necessary preliminary to the determination by the proposed method of evaporation from Lake Superior and stream-flow into it.

In 1922 to September 5, four least-square solutions for determining the evaporation from the surface of Lake Michigan-Huron and the stream-flow into it had been completed. Each solution involved the use of either one month of observation or six months. On September 5, the improved understanding of the problem derived from these four solutions was being used in setting up other solutions which are to be on a more perfect basis and will involve more data. One of the solutions being set up on the date named will involve 28 months of observations—the warmer months of 5 years.

On September 5, 1922, one least-square solution for the determination of the evaporation from the surface of Lake Superior, and the stream-flow into it, had been completed. In this solution observations during a single month were used.

The outcome of the five solutions referred to in the two paragraphs which precede this has been much new information which is primarily of value in indicating what improvements are feasible in the theory upon which later solutions are to be based. In that way these solutions represent decided progress. However, the new information is of little present interest from any other point of view and hence it does not seem advisable to present it here.

The year has been one of steady fundamental progress.

Millikan, R. A., California Institute of Technology, Pasadena, California.
Fundamental researches on the structure of matter.

In November 1921 the Trustees of the Carnegie Corporation of New York appropriated funds to the Carnegie Institution of Washington to be applied for a period of five years in the support of fundamental researches in physics and chemistry at the California Institute of Technology. A portion of this appropriation for the year 1922 was allotted by the Institution to Dr. Millikan for his researches on the structure of matter, concerning which he reports the following activities, although he was absent in Europe from April to September:

The purchase of special research apparatus, the most expensive and the most important of which have been two X-ray machines, one for high-potential work, costing roughly $3,000, and one for high-intensity, low-potential work, costing about the same amount. It is only with powerful apparatus of this type that the problems on radiation and atomic structure can be attacked. A considerable number of small pieces have also been purchased for special problems.

The definite carrying out of a considerable portion of the program outlined for the study of the so-called penetrating radiations of the upper air. These penetrating radiations must apparently have their origins in nuclear changes going on in the atoms of the sun and stars, and their study is therefore a very fitting part of the program for the joint attack on the problem of the structure of matter from both the physical and the astrophysical points of view. Throughout the winter there were constructed in the laboratory in Pasadena special self-registering instruments for obtaining records of the penetrating radiation, the temperatures, and the pressures at all heights up to 20 kilometers. These instruments with their driving and recording mechanism weighed but 190 grams each, the success attained in reducing weight being due in no small degree to the skill of Dr. Millikan's assistant, Mr. Ira S. Bowen, and of the head mechanician, Mr. Julius Pearson. In flights made at Kelly Field with these instruments, during the first two weeks in April, Mr. Bowen and Dr. Millikan, who conducted them, attained altitudes of about 17 kilometers, approximately twice as great as those attained by any previous observers. These results show that the amount of this penetrating radiation existing at these high altitudes is much less than had been supposed. Parallel with these observations Mr. Russell M. Otis has, under the direction of Dr. Millikan, made similar observations in airplanes, in manned balloons, and on mountain tops, with results which are, as far as they go, in agreement with the results obtained by the altitude flights made by Mr. Bowen and Dr. Millikan. It is proposed to push these interesting studies on penetrating radiations during the coming autumn and winter. They have already yielded results which seem to be of much interest and importance.

In order to carry out the large amount of work, both of construction and of observation, involved in the researches described above and in those planned for this fall, a considerable portion of the time of two mechanicians (who have been added to the shop for the purpose) and a group of young observers have been employed. The chief of these last is Mr. Bowen, the major portion of whose time has been devoted to these researches. Mr. Otis has been employed on them for part time, and this autumn it has been arranged to take on four or five others, on part time, in the same way. It is proposed to carry out as rapidly as possible the general program submitted last year.

Nichols, E. L., Cornell University, Ithaca, New York. *Report on studies in luminescence.* (For previous reports, see Year Books Nos. 4–20.)

The Luminescence of Incandescent Bodies.

Throughout the year covered by this report the phenomena connected with luminescence at high temperatures have been under further investigation.

It has been found that when certain refractory oxides and other compounds are heated in the oxy-hydrogen flame to temperatures above those at which the *blue glow*[1] occurs, there are further noteworthy departures from the relations which pertain to ordinary temperature radiation.

This is true of the oxides of the following elements, which are members of groups II, III, and IV of the periodic table:

II.	III.	IV.
Beryllium.	....	....
Magnesium.	Aluminum.	Silicon.
Calcium.	....	Titanium.
Zinc.	Gallium.	Zirconium.

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[1] See Year Book 20, p. 462; also Nichols and Howes, *Journal of the Optical Society of America,* vol. VI, p. 42 (1922).

Certain of the rare earths, i.e. the oxides of gadolinium, samarium, niobium, praesodymium, and neodymium, also of cerium and erbium, should be added to the list.

The effect in question has the following characteristics:

1. It consists of luminescence superimposed upon the ordinary radiation due to temperature.
2. For each substance there is a definite and rather narrow temperature range within which the effect begins, reaches a maximum, and disappears. In some cases two such definite and well-marked crests have been observed.
3. At the maximum the brightness of the substance frequently greatly exceeds that of a black body of the same temperature.
4. The luminescence is highly selective.
5. The intensity of the effect depends on the mode of heating and particularly on the presence of free oxygen.
6. It also depends on the previous heat-treatment of the substance.
7. It is subject to fatigue.
8. The temperature range is that during which the substance is undergoing some profound physical change or rearrangement and the crest coincides in temperature with some transformation point.

THE PHOTO-LUMINESCENCE OF FLAMES.

In connection with these studies of the luminescence of incandescent bodies, investigations of the conditions within the flame itself are in progress.

In the case of the hydrogen flame in air the following quite unexpected effect has been discovered: When such a flame is rendered luminous by the introduction of a salt of lithium, sodium, calcium, barium, or strontium, *the intensity of the bright bands of the flame spectrum is modified by exposing the flame to light.*

In the preliminary observations, now in progress, enhancement of these bands (e. g., of the sodium lines, the lithium line at 0.6708μ, the red, orange, and green bands in the spectrum of calcium and strontium) has been produced, respectively, by light from the tungsten filament of a nitrogen-filled lamp, from a carbon arc, and from an iron spark. The increase in brightness has in some experiments exceeded 10 per cent of the initial intensity of the band.

The active rays appear to lie among the shorter wave-lengths, but not in the far ultra-violet.

Light of the same wave-length as that in a given band, instead of enhancing the band, by resonance, *has a quenching effect.* Thus sodium light focussed upon a sodium flame tends to inhibit its enhancement by exposure to shorter wave-lengths; light passed through a ruby glass has the same quenching effect on the lithium flame; white light filtered through an ammonio-sulphate solution is more effective as an excitant than the same light, unfiltered, etc.

The phenomenon is strictly analogous to the well-known quenching effect of infra-red upon the luminescence of certain sulphides, and one is led to ask whether we do not in these experiments have to deal with the luminescence of finely divided solids (possibly particles of Na_2O, Li_2O, CaO, etc., respectively) instead of with the glowing vapors of the elements.

NEW OBSERVATIONS ON THE LUMINESCENCE OF THE URANYL SALTS.

When (in 1915) Professor H. L. Howes[1] described the remarkable changes produced in the fluorescence spectra of frozen solutions of certain uranyl salts upon cooling to the temperature of liquid air, it was suggested that the phenomena were probably due to the formation of definite hydrates. Professor F. E. E. Germann,[2] who took up the question from the point of view of the physical chemist, has now succeeded in establishing the existence of at least one such hydrate ($UO_2(NO_3)_2 . 24H_2O$), the temperature of formation of which, −35° C., corresponds to that of some of the most striking changes recorded by Howes, whose explanation is thus confirmed.

The complete mapping of the absorption spectra of uranyl salts has been subject to unusual difficulties because of the opacity of these substances in the ultra-violet. Dr. L. J. Boardman,[3] in an investigation just published, has greatly extended the map of these spectra by means of the principle previously established by H. E. Howe,[4] that regions of the spectrum capable of exciting fluorescence coincide as to wave-lengths with the absorption bands of the fluorescing substance. The numerous bands thus mapped by Boardman are new members of the absorption series previously known. Many of them lie in the ultra-violet beyond the range of previous measurements; others are hitherto undiscovered reversals of fluorescence bands.

Within the present year, the relative brightness of many fluorescent materials has been quantitatively determined for the first time,[5] for which purpose an optical pyrometer of the Morse type was calibrated to read in millilamberts instead of temperatures. The two brightest substances thus far tested are uranyl compounds, i. e., potassium uranyl sulphate, 35.2 millilamberts; ammonium uranyl sulphate, 23.0 millilamberts. These are followed by luciferin (Harvey) 16.0 millilamberts; synthetic willemites, 14.0 millilamberts, sidot blende; 10.9 millilamberts.

PROGRESS OF THE WORK ON PHOTO-ACTIVE CELLS.

Under the direction of Professor C. C. Murdock further studies relating to the photo-active cells have been in progress:

Mr. K. F. Sun has developed a method for determining the variations in electrolytic resistance and electrolytic capacity with temperature, concentration, and applied potential difference.

Mr. Irving Wolff has devised another method for the capacity of such high-resistance cells by which it will be possible to find the change of capacity with frequency.

Miss Clara Cheney is working upon the migration ratio in the electrolyte (rhodamin B) which is used in these photo-active cells.

MISCELLANEOUS STUDIES.

The investigations of Professor Frances G. Wick upon the kathodo-luminescence of certain fluorites containing traces of the rare earths are nearly completed and the results will soon be published. The interpretation of the complicated spectra of these substances with their line-like bands has long been a subject of controversy.

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[1] Howes: Physical Review (2), vol. VI, p. 192 (1915).

[2] Germann: Physical Review (2), vol. XIX, p. 623 (1922).

[3] Boardman: Physical Review (2), vol. XX, p. 552 (1922).

[4] Nichols: Proc. Am. Philos. Soc., vol. 56, p. 258 (1917).

[5] Nichols: Science; vol. 55, p. 157 (1922).

In collaboration with Professor Bridgman, of Harvard, she has also made an important study of the action of high pressures, up to 3,500 atmospheres, upon the absorption spectra of various substances, with results by the use of which it will be possible to compare definitely the effects of pressure with those of cooling.

Dr. Tanaka is engaged in a detailed spectro-photometric study of substances whose kathodo-luminescence depends on the presence of traces of an activating element such as copper, manganese, lead, bismuth, zinc, or silver. He has confirmed Dr. Howes's discovery that the spectra of such compounds (a class which includes the Lenard and Klatt sulphides, the commercial phosphorescent sulphides of zinc and of calcium, etc.), although they appear to the eye to consist of one or two very broad bands covering the greater part of the visible spectrum, are really made up of numerous, equidistant, overlapping components.

Dr. Tanaka finds furthermore that the *position and interval of the components depend only on the activating material* and are the same whatever the solid solvent and flux; also that there is a perfectly definite relation between atomic weight and interval such that activating elements, when unknown, can be identified from the interval.

Miss M. A. Ewer is making a detailed mathematical study of the structure of flame spectra with special reference to the question of the series of constant frequency intervals. She has developed a graphic method based on the doctrine of congruences, by which it will be possible to determine whether such intervals as are found by other methods show real or only apparent series.

She finds that the numerical relation is one of rather close approximations, not of absolute values; but that, despite this fact, the grouping is real for some at least of the elements giving a flame spectrum. Other elements are still under investigation.

The intervals so far found, both in the investigations of Dr. Tanaka and those of Miss Ewer, are related inversely to the atomic numbers of the elements.

Mr. D. T. Wilber has been engaged throughout the year in the study of the very intricate and puzzling question of the *effects of heat-treatment on the activity of various luminescent compounds.* Dr. H. Kahler is investigating the equally difficult problem of the *relations of photo-electric properties to luminescence.*

SEISMOLOGY.

[For previous reports see Year Book No. 20, pages 175 to 178.]

REPORT OF THE ADVISORY COMMITTEE.

In 1921 the Advisory Committee in Seismology recommended to the President and Trustees of the Carnegie Institution of Washington that the Institution enter the field of Seismologic Research, taking up at the outset the pressing problem offered by the West Coast region of the United States, where earth movements in considerable variety occur and so little is known about them that they constitute a tangible menace to large engineering and other development enterprises and sometimes to human life. It was pointed out that appropriate instruments for the study of such local earth movements have not been developed hitherto and are very much needed. Furthermore, as research is organized in the United States, no other institution is in position to take up such a task single-handed because of the number of different considerations involved in attacking the problem satisfactorily. It was therefore recommended that the Institution invite the participation of a number of agencies, through the cooperation of which an adequately comprehensive attack might be inaugurated and competent conclusions assured.

In particular it was recommended that the Ukiah and Lick Observatories be invited to continue and extend their observations of latitude for the purpose of establishing (or disproving) a northward crustal creep or drift which had been indicated by earlier observations; that the U. S. Coast and Geodetic Survey be invited to extend its system of primary triangulation and precise levels until no considerable area within the various zones of movement in California can suffer displacement without the possibility of establishing its direction and magnitude; that the U. S. Geological Survey, in collaboration with the California universities and geological societies, be invited to organize geologic studies of the regions in which the more active faults occur; that the California Institute of Technology, the Mount Wilson Observatory, the U. S. Bureau of Standards (Washington), and any others interested, be invited to aid in the development of instruments more suitable than any now in use for recording and analyzing local slips and tremors; and finally, that the effort be made to obtain from the Navy Department deep-sea soundings off the west coast of California to establish the precise location of the continental shelf and any other conspicuous fault scarps adjacent to the land areas in which active faults are found.

These recommendations were considered favorably and this committee was asked to continue its organization for another year for the purpose of arranging with the institutions mentioned a practicable basis of cooperation through which the various desiderata named above might best be accomplished. This task was accepted by the committee, and during the past year an effort has been made to organize working arrangements through which the proposed plans may be carried out. Just here it may appropriately be said that without a single exception every institution invited has been glad to join in a systematic study of this kind and ready to aid to the fullest extent of its power, and the organization—the first, be it said, of this magnitude which has been attempted in American research—promises to be a most effective one. This is a tribute not only to the scientific soundness of the problem under consideration, but to the readiness of American scientific bureaus and institutions to advance research even when not in the direct line of their immediate program.

Not only has the full program been adopted as proposed, but work has been begun and no inconsiderable progress made in each of the directions considered. This progress may be reported under the several headings of the proposal of last year, as follows:

1. Study of Geological Formation along the California Fault Lines.

Work on California fault-zone geology was begun by the appointment of a local subcommittee in California under the chairmanship of Professor Bailey Willis, of Stanford University. Associated with him were Professor A. C. Lawson and Dr. Ralph Arnold, members of the Advisory Committee, Mr. Fred P. Vickery, of the Southern Branch of the University of California, and Mr. L. S. Noble, of the U. S. Geological Survey. To this subcommittee was intrusted the task of preparing a plan for a thorough geological study of the faulted regions of California. Such a plan has been prepared and work was begun at once by the representatives of the Geological Survey, aided as opportunity offered by the other members of the committee, and in particular by Chairman Willis. Sections of the San Andreas fault, which is perhaps the most important zone of weakness, were assigned to different members of the subcommittee, and some of these have received thorough study during the first year.

Perhaps the first tangible result of this study will appear before the end of 1922 in the form of a fault map in which these zones of structural weakness, so far as known, will be laid down. It can not make any pretension to completeness, in view of the immense territory involved and the short time available for the undertaking, but perhaps the very gaps themselves will stimulate interest in its completion. A special report of the chairman of the subcommittee on Fault-zone Geology is appended.

2. Surface Displacements.

The U. S. Coast and Geodetic Survey has been much interested to undertake an accurate triangulation of those regions of California which are particularly subject to earth movements, and with the support of such influential organizations as the Commonwealth Club of San Francisco, the American Institute of Mining Engineers, the Seismological Society of America, and Senators and Representatives from California, who have shown much interest in the economic phases of the proposed studies, has obtained an appropriation of $15,000 for the fiscal year beginning July 1, 1922, with which to inaugurate this work. Arrangements were complete for beginning the work as soon as the funds were available, and a system of triangles is now being established extending from San Francisco Bay across the important zone of movement of 1906 to the older formations of the Sierras at Reno. This work is expected to be completed before the snow appears in the mountains. It will be followed in the spring by further work in a locality to be selected later. It is the purpose of the Director of the Geodetic Survey to apply to this task the most precise methods hitherto developed in order that the closest possible control may be established of the important landmarks in this zone of movement.

It is of particular importance that this triangulation will be completed at a time when no great earthquake has occurred for many years. The observations of 1907 were made immediately following the great earthquake of 1906. If the earth's crust had been seriously strained by drift and the great earthquake represented the release of that strain through fracture, no information regarding the character or direction of the strain would be gained by position measurements immediately after the release. If such a drift has continued since 1906, as the observations of the astronomers indicate, we have now the opportunity of locating essential points in the region at a time when the strain is probably considerable.

3. Southern California.

The preparation of preliminary plans for work in southern California has been in the hands of the Research Associate in Seismology of the Carnegie Institution, Mr. H. O. Wood, in collaboration with the California Subcommittee on Fault-zone Geology. During the past year Mr. Wood has devoted his whole time (1) to the development of appropriate instruments for the study of tremors, of which more detailed information follows; (2) to a field study of the southern portion of the State, with a view to the appropriate location of triangulation points for the Coast and Geodetic Survey as soon as it is prepared to extend its work to this region; (3) to mapping the zones of structural weakness in a part of the State in which more extensive and intricate faulting has occurred than elsewhere, and which happens not to have been so extensively studied hitherto as the more northern portions. For the same reason a considerable proportion of the time of Messrs. L. S. Noble and W. S. W. Kew, of the Geological Survey, has been given to this region. These studies are to be continued by the same individuals during the coming year and will result in very careful preparation not only for the triangulation work of the Geodetic Survey, but also for the establishment of stations mounting the instruments through which it is proposed to locate the origin of land-slips and tremors.

4. The Development of Instruments.

The development of instruments of appropriate sensitiveness to detect local shocks of short period appears never to have been seriously undertaken in seismology, but in the success of this particular research it was thought to be the most vital factor. Dr. J. A. Anderson, of this committee, has given much attention to the subject throughout the year. Associated with him were Mr. Wood, whose experience was most valuable because of his attempt to record such shocks emanating from the volcanoes of the Hawaiian Islands during the period from 1912 to 1917; Mr. Francis G. Pease, of the staff of the Mount Wilson Solar Observatory, who designed the system of chronographic registration; Dr. Frank Wenner, of the U. S. Bureau of Standards, who has had especial success in the development of galvanometers for such unusual purposes, and who undertook a special trip to California under leave of absence from his duties in Washington to associate himself for a time with this enterprise; Professor Arnold Romberg, of the University of Hawaii, who has given several years of study to this problem of seismographic record in connection with his studies of Hawaiian earthquakes; and finally, Professor Millikan, of this committee, who, with his associate in the California Institute of Technology, Dr. W. T. Whitney, and his skilful mechanician, Mr. Pearson, undertook the construction, in the shop of the Institute, of the instrument which was planned.

After several conferences these gentlemen agreed upon the desirability of proceeding along two lines: (1) to build a sensitive vertical seismograph for the measurement of earth displacements during shocks; (2) to design a sensitive accelerograph for the measurement of the acceleration of movement. These two sets of instruments are now under construction in Pasadena.

The general plan of procedure for this phase of the investigation assumes that the earth faults will give evidence of their activity by occasional slips which will cause disturbances to travel outward from points of structural weakness as wave pulses. To obtain definite information concerning the location of the sources and the direction of movement of these slips, it is considered necessary to record accurately the motions which find expression in these wave pulses and the relative times at which the pulses arrive at two or more observing-points. The requirements for such instruments are, first of all, sensitiveness and reliability to a degree not obtainable from seismometers, such as are now in use in the usual teleseismological observation stations. The plan for one of these sets of apparatus is patterned somewhat after that of Prince Galitzin, in which use is made of the usual pendulum mounted so as to have a period of the order of 10 seconds, recording photographically on moving sensitive paper the beam of light reflected from a galvanometer mirror. The galvanometer is connected to a coil of insulated wire attached to the pendulum and placed in the field of a strong magnet fixed to the pendulum support. When there is relative motion between the pendulum and its support an electromotive force is developed in the circuit which gives a current and consequently a deflection of the moving element of the galvanometer. In this system the deflections are arranged to be approximately proportional to the relative displacements of the pendulum and its support, that is to say, the earth at the point of observation. The present design is planned to record pulses having effective periods varying from 0.05 to 2.0 seconds, and any magnification desired up to 500. It is hoped that a field test of this instrument can be made before the close of the present calendar year.

5. Soundings.

Through the cooperation of the Navy Department, the Hydrographic Office has arranged to equip two destroyers with appropriate sounding devices and, as soon as they are ready, to undertake an elaborate network of soundings from Los Coronados at the Mexican boundary to Point Conception, and perhaps farther north if the results warrant it. This region is opposite the great fault zone of southern California and the determination of the faults there will complete our information regarding lines of structural weakness in the region to which the most intensive study is proposed to be given. These soundings will begin about the middle of October 1922 and are expected to yield a more complete map of the undersea configuration than has ever been developed hitherto.

6. Isostasy.

The problem of isostatic adjustment and its possible relation to crustal movement depends, at the moment, primarily upon the possibility of obtaining a very much greater number of well-distributed measurements of the constant of gravitation than are now available. But this must also await the design of a new instrument for the purpose which is capable of attaining to an accuracy of one part in a million and is light enough to be carried about by hand. Such an instrument would permit determinations at a great number of places and would not be limited in use to places of easy accessibility as now. Such an instrument in the hands of the U. S. Coast and Geodetic Survey would soon provide a tangible connection between the gravitational anomalies which are everywhere found in the West Coast region, and the physical structure and distribution of density in the Earth's crust.

The design of a more appropriate instrument has been undertaken by the Geophysical Laboratory of the Carnegie Institution with the cooperation of the Coast and Geodetic Survey.

It is not possible within the limitations of an administrative report to give details, even essential ones, of so comprehensive a program, but a very strong group of institutions has been brought together here with the single purpose of elucidating the problem of the California earth movements from every practicable viewpoint. It is a problem of equal importance to the science of seismology and to the economic life of one of the most active and prosperous regions of the United States. Your committee, therefore, earnestly recommends the continuance of the support hitherto given to the organization which has been effected, together with appropriate provision for the construction of additional instruments, as soon as the new designs shall have proved effective and stations are established for their installation and continuous service.

It is further recommended that Mr. H. O. Wood, Research Associate in Seismology, be continued in charge of the field reconnaissance and any seismograph stations that may be established.

J. A. ANDERSON,
RALPH ARNOLD,
W. W. CAMPBELL,
ARTHUR L. DAY (Chairman),
A. C. LAWSON,
R. A. MILLIKAN,
HARRY FIELDING REID,
BAILEY WILLIS,
Advisory Committee in Seismology.

Carnegie Institution of Washington,
September 1922.

PALÆONTOLOGY.

Case, E. C., University o Michigan, Ann Arbor, Michigan. *Study of the vertebrate fauna and palæogeography of North America in the Permian period, with especial reference to world relations.* (For previous reports see Year Books Nos. 2, 4, 8–20.)

A report on the preliminary work upon the discoveries made in the upper Triassic of western Texas was printed in the Year Book for 1921. The work has been completed and the final report has been issued entitled "New Reptiles and Stegocephalians from the Upper Triassic of Texas."

During the summer of 1921, exploration for the discovery of other fossiliferous beds in the upper Triassic was carried out on both sides of the Staked Plains with but little success. However, relations were established with parties interested in the local areas, and it is hoped that new localities may be discovered and reported.

With the reestablishment of the possibility of scientific work abroad, work upon the relations of the Permian deposits of North America to the Permian deposits in other parts of the world will be resumed. Dr. Case sailed for Europe about the middle of July 1922 and will remain abroad for fourteen months, examining the Permian deposits and the collections in the museums in Europe, South Africa, Australia, and India.

Hay, Oliver P., U. S. National Museum, Washington, District of Columbia. *Report on work done on the Pleistocene epoch and its vertebrate fossils.* (For previous reports see Year Books Nos. 11–20.)

During some months following his last report the writer was engaged in studying the Pleistocene geology of the Great Basin region of Utah and Nevada and the Pleistocene vertebrates there discovered. Essential to the understanding of the problems there presented are G. K. Gilbert's *Lake Bonneville* (Monogr. U. S. Geol. Surv., Vol I) and I. C. Russell's *Geological History of Lake Lahontan* (Monogr. U. S. Geol. Surv., Vol. XI). Important aid is furnished by Dr. Wallace W. Atwood's paper on his investigations on the Wasatch Mountains (Profess. Pap. U. S. Geol. Surv. No. 61) and Dr. John C. Merriam's report on vertebrate fossils found at Astor Pass, Nevada (Bull. Dept. Geol. Univ. Calif., Vol. VIII, pp. 377–382). From a study of these and other authorities the writer concludes that the deposits of white marls (the Upper Bonneville) at Lake Bonneville and Russell's Upper Lacustral clays at Lake Lahontan belong approximately to the Aftonian stage, while the yellow clays at Lake Bonneville and the Lower Lacustral clays at Lake Lahontan are to be referred to the Nebraskan stage. Unfortunately the number of species of fossil vertebrates discovered in the Lake Bonneville deposits is very few and of little value. Those found in the Lake Lahontan region, horses, camels, and an extinct tiger, throw distinct light on the age of the beds, but here again the material is scanty.

The writer has also devoted some time to the study of problems connected with the Pleistocene geology of Iowa, where all of the glacial stages are well represented and likewise most of the interglacial stages, if not all.

Since the beginning of 1922 the writer has been occupied mostly in revising the manuscript and seeing through the press the "The Pleistocene of North America and its vertebrate animals." It will form publication No. 322 of the Carnegie Institution of Washington.

Wieland, G. R., Yale University, New Haven, Connecticut. *Associate in palæontology.* (For previous reports see Year Books Nos. 2–4, 6–9, 11–20.)

Preceding reports in the Year Book outline the main topics of fossil gymnosperm research still in hand. Emphasis rather than modification of these outlines is recorded. The consistent aim during the past year has been, as before, to study the major problems of gymnosperm evolution primarily from structure and distribution, chiefly in the Mesozoic rocks.

As no field work has been done during the past two years, accessions of material have been limited to several casually reported finds. One in the Comanchean of Texas indicates a petrified cycadeoid extension of importance.

Last winter Mr. Handel T. Martin, of the State University of Kansas at Lawrence, forwarded a small armor fragment of a large petrified cycadeoid from the Niobrara Chalk. This is very gratifying as being absolutely the only known American occurrence between the Potomac, the Trinity beds, the Dakota, and the Como, and the much later stems of the Upson shale and the Belly River beds. Moreover, on sectioning, the specimen was found to add one more species to the series of monocarpic cycadeoids. With this addition in view, the general subject of monocarpy, as so remarkably exemplified by the cycadeoids, requires a brief word here.

MONOCARPY IN THE CYCADEOIDS.

In the early work on the petrified cycadeoids it was observed that in some instances large and evidently quite mature trunks bore few or no fruits, while several monotypic species bore either a full complement of old or very elongate peduncles or else the young undeveloped fruits in the axils of all old leaf-bases. Such culminant fructification is commonly termed monocarpy.

Some years later it was possible to add in demonstration the very remarkable fossil plant, *Cycadeoidea dartoni*, bearing a full series of hundreds of mature seed cones; while still later, an illustrated statement of the evidence for monocarpy was given in the *American Journal of Botany* for April 1921. But with one more species at hand from a marine horizon so well known for its reptiles, fishes, and occasional dinosaurs, these instances of monocarpy seem more directly significant. The monocarpic cycadeoids are the following:

	Fruit stage.	Locality.	Age.
Cycadeoidea marylandica (var. C. fisheræ).	Very young fruits.	Maryland.	Potomac.
masseiana.......	Very young fruits.	Apennines, Italy.	Scaly clays.
stanteoni.......	Old peduncles.	California.	L. Cretaceous.
nigra...........	Old peduncles.	Colorado.	L. Cretaceous.
dartoni.........	Mature seed cones.	Dakota.	Dakota Cret.
nev. sp..........	Old peduncles.	Kansas.	Niobrara Cret.

That is, the highly specialized columnar monocarpic cycadeoids stretched across North America and later extended from the basal Cretaceous, past the Benton, into the lands about the Niobrara Sea. Besides, the series early reached cosmopolitan distribution (on the thirtieth parallel).

Concisely put, the age of the several monocarpic species at fructification can not be fixed from isolated types widely separated geographically. Only some rare occurrence of many examples at a restricted point could yield the final data. But the numerical relation between young leaf-crowns to the old leaf series in forms not distinctly monocarpic may be considered, as well as a slight tendency to form growth rings. The types were long-lived, and it can therefore be asserted only that the monocarpic character was developed to such an extent that it could readily become regional in both these and related plants. These studies hence emphasize the fact that monocarpy is progressive in its origin, varied of phase, ecologic in significance, and until recently much in need of redefinition by botanists.

Thus is outlined the first expression of monocarpy discovered in the gymnosperms, and of course the only instance recognized in ancient plants. It means much. The cycadeoids had a varied unisexual and bisexual floral development, and they reached their very highest degree of specialization in the monocarpic type. Culminant fruiting, in fact, developed in the widely distributed, specialized, long-lived type, in as pronounced form as in the modern bamboos. The more readily could the habitus characterize innumerable less conspicuous, generalized relatives. Such we have every right to hypothesize in tens of thousands of species.

While, then, the monocarpic cycadeoids are as stubbornly specialized as any gymnosperms in their vegetative features, a definite monocarpic trend quite unexpectedly indicates a high range of plasticity. Other slender-stemmed and branched types or their dwarf relatives would everywhere come under the average soil and moisture conditions of the copse, or of the more open scrub or bushy to grassland association—the lesser vegetation more or less antecedent to early dicotyl development. For an early presence of monocarpy is not only thus established, but even the factors which produced it come into view.

Here, too, are other possibilities, additional explanations of how readily the early cycadeoids could modify in the direction of the present-day seed-plant dominants. With perhaps much of reduction in many instances, the rise of the simpler monocarpic dicotyls, the annuals and biennials, would thus always be coordinated with the forest-forming perennials, in all formations and successions. It follows, moreover, that any hypothesis of dicotyl derivation from the coniferales rather than the cycadeoids, should be based on evidence of widespread occurrence in the early Mesozoic of bisexual coniferous flowers, and at least some indications of a prevailing monocarpic tendency. So far such evidence within the coniferales is notable for its absence.

Another year has passed without direct university cooperation in these elaborations of important material, but the Washburn College at Topeka, Kansas, forwarded for examination a singularly unique cone or head attached to its stem, from the lower Cretaceous of Ellsworth or an adjacent county. This is described along with some other material in a Bulletin of the Canadian Geological Survey shortly to appear. The Harvey Lewis Company of New Haven, mentioned in last year's report, has given further aid on thin sections.

Efforts extending over several years to have the great Minnekahta cycad locality segregated and protected because of its extreme scientific and general interest and value can now be reported as successful. President Harding has recently signed and sent to the State Department the proclamation for the creation of the Fossil Cycad National Monument of South Dakota.

Merriam, John C., and associates. *Continuation of Palæontological Researches.* (For previous report see Year Book No. 20.)

In the course of the year 1922 the general program of work by Mr. Merriam and associates has been conducted in close cooperation with the Museum of Palæontology of the University of California, the Los Angeles Museum, the United States National Museum, the American Museum of Natural History, and many other institutions working upon similar or related problems.

As in the year 1921, the group of investigators engaged upon problems involving the history of life in the Great Basin and Pacific Coast regions has included especially Dr. Chester Stock, Assistant Professor of Palæontology at the University of California, Mr. Remington Kellogg, of the Bureau of Biological Survey, U. S. Department of Agriculture, Dr. Ralph W. Chaney, Research Associate of the Carnegie Institution of Washington, Dr. L. H. Miller, Professor of Zoology, Southern Branch, University of California, Mr. E. L. Furlong, Curator in the Museum of Palæontology, University of California, and J. C. Merriam.

Although the persons undertaking this study have approached the subject from different directions, the aim of the group has been to secure information on the history of animal and plant life of the Great Basin and Pacific Coast regions which can be fitted into an established geological sequence for this region. The ultimate goal is the relation of data on life history of western North America to the general scheme of world history. It involves the significance of climatic fluctuations, difference in distribution of land and water, migration of faunas and floras, and all physical or biological factors which through their expression in history may have value in attempting to interpret the growth movement, or evolution, in the life world.

Dr. Chaney has been engaged in an attempt to secure additional materials from a wide range of localities, both in the Pacific Coast and Great Basin regions, in order that he may have a succession of floras related to the geological deposits of definitely determined age. The lack of systematic and intensive study of the history of plants on the Pacific Coast has made it difficult for those palæontologists who have studied West Coast floras to secure typical stages in plant life such as are needed as a basis for comparison in all historical studies. Dr. Chaney has also given close attention to an investigation of the relation of the plants discovered to their environment. This has involved a study of the character of the strata and the nature of the sediments composing the geological formations. This work has been done in cooperation with Dr. Clements, of the Division of Ecology, Dr. W. D. Matthew, of the American Museum of Natural History, Dr. George W. Louderback, of the University of California, and Dr. T. Wayland Vaughan of the U. S. National Museum.

Dr. Chaney has also paid especial attention to the relation between the sequence of stages in plant life and the corresponding sequence in higher animals (especially the mammals) and the lower forms of animal life as represented by the mollusks in the marine formations of the coastal region of California and Oregon.

The work on the history of plants conducted by Dr. Chaney has also involved a much more careful study of the types of life or the species than has heretofore been possible with materials from the Pacific Coast region. Palæobotanists have worked at a disadvantage in the past in the study of

Pacific Coast collections, by reason of the limited material and inadequacy of the specimens for study of the whole plant. In order to give palæobotany the same opportunity for interpretation of periods on the earth in the past as is possible through the history of animal forms, we must be able to discuss the relations of the plant, including stem, leaves, flowers, and fruit, as in the case of botanical studies of the present day.

The progress made in the course of the past year in the relation of palæobotanical studies to other studies on the West Coast is very encouraging, and there is reason to believe that we may be able to develop this phase of the geological and biological problem in the historical sense to the extent that new and significant interpretations may be put upon much of the historical data heretofore difficult to understand.

Mr. Remington Kellogg, who has cooperated with us in the study of extinct marine mammals, has examined a considerable amount of new material from the West Coast during the past year through the assistance of Mr. E. L. Furlong and Dr. Chester Stock. At the same time, the U. S. National Musuem has very kindly developed, for Mr. Kellogg's use, large collections of fossil marine mammals from the Atlantic Coast. This study includes both the whale and seal groups and has led to a better understanding of the history and evolution of both of these divisions from the West Coast of North America than has heretofore been possible. Through Mr. Kellogg's synchronous study of the forms from both East and West Coast, he has made greater progress in understanding these faunas than would have been possible with the investigation of one fauna alone. His contribution of three important papers on this subject during the past year, with three others accepted for publication and three important studies in progress, makes a noteworthy advance in this field of the study.

Mr. E. L. Furlong has cooperated with Dr. Stock, Mr. Kellogg, Dr. Chaney, Dr. Miller, and Mr. Merriam in the arrangement and organization of collections in the Museum of Palæontology at the University of California. He has carried on field work in the asphalt deposits at McKittrick, California, in the marine deposits containing mammals of the seal and whale groups, and in the formations containing fossil plants and fossil mammals in eastern California and the Great Basin region. The assistance of Mr. Furlong, together with that of Dr. B. L. Clark, Director of the Museum of Palæontology of the University of California, has helped to advance studies which otherwise could not have been accomplished.

Dr. Chester Stock has continued his work on the fossil faunas obtained from the Pleistocene asphalt deposits of Rancho La Brea and McKittrick and has also undertaken field work in the deposits belonging to the western border of the Great Basin region. Rapid progress has been made in this work and the result of many years' study on the ground-sloth group are presented for publication by Dr. Stock in the form of a monograph of exceptional interest and importance. Dr. Stock has also cared for the preliminary measurements in correlation of the details of comparison involved in the studies of Mr. Merriam on the groups of Carnivora in the Rancho La Brea fauna and has joined with Mr. Merriam in the preparation of a paper on the fossil bears of the Pacific Coast region. Dr. Stock has now in preparation a monograph on one of the groups of hoofed animals from the Rancho La Brea fauna.

In connection with the work of Dr. Stock and Mr. Merriam on the faunas of Rancho La Brea and McKittrick, Mr. John L. Ridgway, formerly connected with the Carnegie Institution of Washington, has rendered most valuable service in the preparation of illustrations for the forthcoming monographs.

Of peculiar interest in connection with the study of the history of West Coast faunas is the work of Dr. L. H. Miller, of the Southern Branch of the University of California, on the fossil birds found in the asphalt deposits at McKittrick, California, and on the remarkable collection of bird remains found in the great deposit of diatomaceous earth at Lompoc, California. The history of birds is one of the most interesting chapters in the whole story of evolution, but the material known up to the present time is comparatively scanty; the contributions of Dr. Miller are therefore of extraordinary interest.

One of the most important features of the year's work is an evidence of the importance of cooperative work. In connection with the studies of Dr. R. W. Chaney on the succession of floras of the gold-bearing gravels on the west slope of the Sierra Nevada it became necessary to make an investigation of the floras at Tuolumne Table Mountain. The suggestion of such investigation was made by Dr. F. E. Matthes, of the U. S. Geological Survey, who has secured interesting information regarding plants in their relation to the geology of this region. In visiting this locality to secure further plant material Dr. Chaney discovered a number of fossil remains of horses and camels embedded in the volcanic deposits of the Table Mountain region. These remains give the first unequivocal evidence as to the age of these deposits. The remains of horses included in this collection are closely similar to those from the Ricardo Pliocene formation in the Mojave Desert region on the east or southeast side of the Sierra region. This evidence of early Pliocene age of these deposits at Table Mountain has a very important bearing on the whole question of the age of the Sierras and on the significance of crustal movements which have affected the climatic character of the Great Basin region to the east.

The work of the past year has demonstrated more clearly than ever the necessity for close cooperation and correlation of effort in order to secure the best results in study of the history of life. The materials are necessarily fragmentary, widely scattered, and difficult of interpretation, and only by such cooperation as will give perspective by viewing the subject from different positions can we expect to secure data which will lead to a correct interpretation of the sequence.

Chaney, Ralph W., Berkeley, California. *Research Associate in Palæobotany.* Report of progress in palæobotanical research in the Tertiary of the West during the year 1922.

The work of the year has again centered in the northern portion of the Great Basin. Further collections and areal studies in the Crooked River Valley indicate that the Tertiary section there exposed is probably identical with that of the John Day Basin 40 miles to the north. An ecological analysis of the Upper Clarno flora indicates the presence of numerous valley or lake border trees with a mixture of upland types, the whole denoting a temperate-climate assemblage in a region of moderate relief. Collections from several horizons show the same group of dominant species, indicating a recurrence at least twice of conditions suitable for the development of the Upper Clarno forest. The local abundance of *Sequoia* may be interpreted as indicating the presence of relatively humid habitats in which this genus predominated.

The study of the Payette flora from western Idaho indicates the Miocene age of the Payette formation. Although related to the Mascall flora of the John Day Basin, the Payette shows certain characteristics which indicate a greater aridity and a higher relief than are presumed to have existed in central Oregon during the Miocene. Such climatic and topographic variations over distances of a few hundred miles may be expected to have existed then as they do now.

Collections from western Nevada indicate the importance of this area in correlating the Tertiary section of the Great Basin with those of the Coast Ranges and the Auriferous Gravels. There is reason to believe that a much more extensive record of the Tertiary plants of this critical area will be found during subsequent field seasons.

Through the help of Dr. F. E. Matthes, my attention has been directed to a fossil-leaf locality in the Auriferous Gravels at Table Mountain, Tuolumne County, California; vertebrate remains were also secured in the same general region. The plants occur in a layer of andesitic tuff associated with gravels, both overlying the grano-diorite bedrock. Of the 16 species, 9 are known only from the flora of the Auriferous Gravels; 2 species are restricted to the Eocene and Oligocene, 3 range from the Eocene into the Miocene, and 2 are restricted to the Miocene. Of these latter, *Platanus dissecta* is one of the most widespread and characteristic forms of the Miocene. The total lack of knowledge regarding the Pliocene plant life in the West makes it impossible to be certain that the Table Mountain flora is not of Pliocene age, the age indicated by the associated mammalian remains. Considering that the Pliocene flora is practically unknown, the flora would probably be recognized as Miocene.

Numerous short trips have been made to fossil-plant localities in the Coast Range region near Berkeley. On one of these a forest of petrified Sequoias was visited in company with Doctors Day and Allen, of the Geophysical Laboratory. While the fossil floras of this province do not show the variety and excellence of preservation which characterize those of the Great Basin, they will ultimately be of great value in correlation since they are associated in the Tertiary section with numerous invertebrate faunas whose age is known.

A trip from Berkeley to Agate, Nebraska, in company with Dr. Frederic E. Clements, resulted in the discovery of a considerable amount of silicified wood. Plans are already under way to utilize this type of material in checking generic determinations based on the leaves. Studies of the origin of Tertiary sediments were made, especially in that portion of the territory east of Salt Lake City, where Dr. W. D. Matthew was a member of the party.

Mr. Robert H. Seashore, of the State University of Iowa, acted as field-assistant during the greater part of the summer.

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